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WEEKLY 8 May 2021

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The countries at risk of following India into crisis

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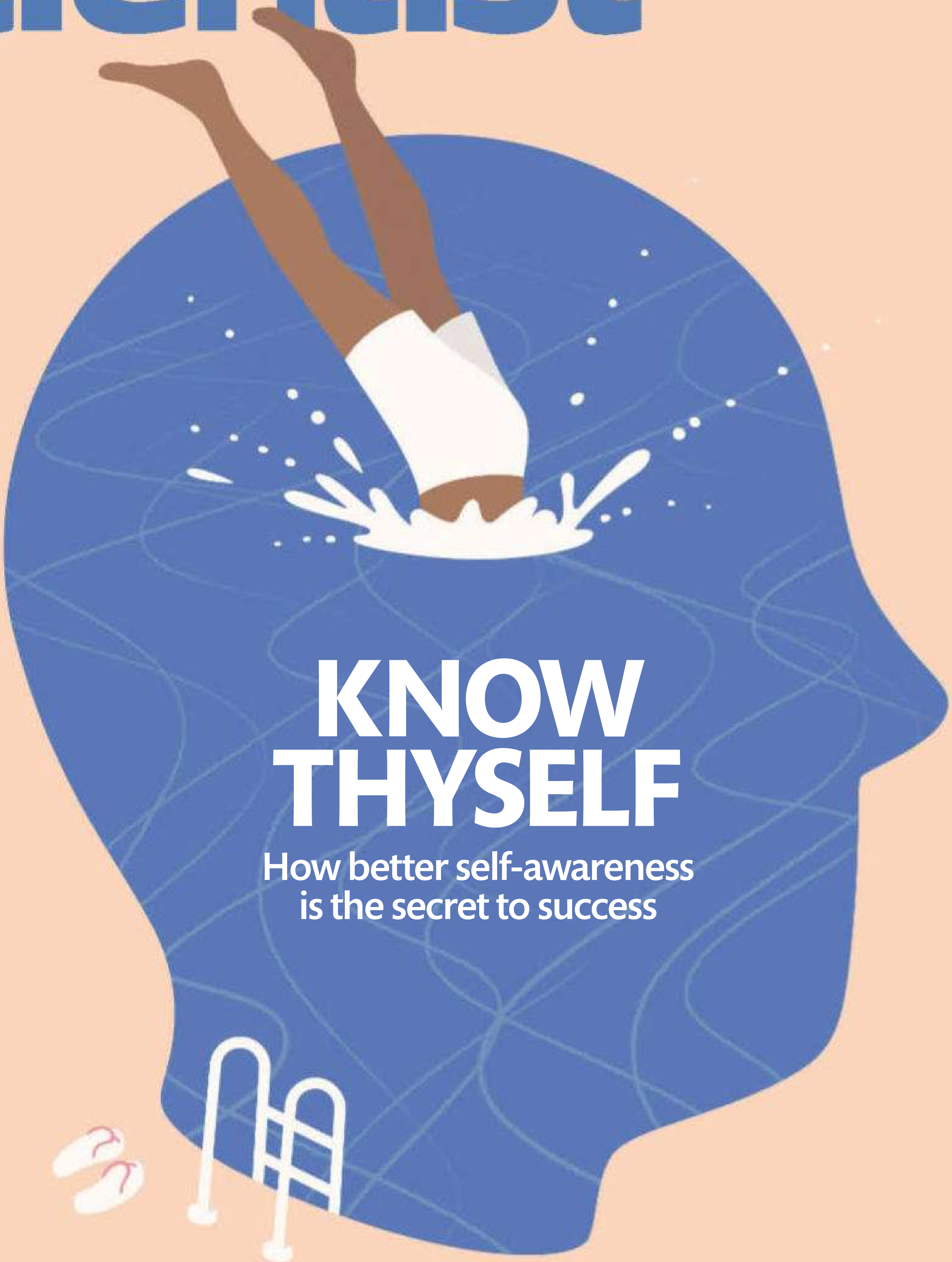

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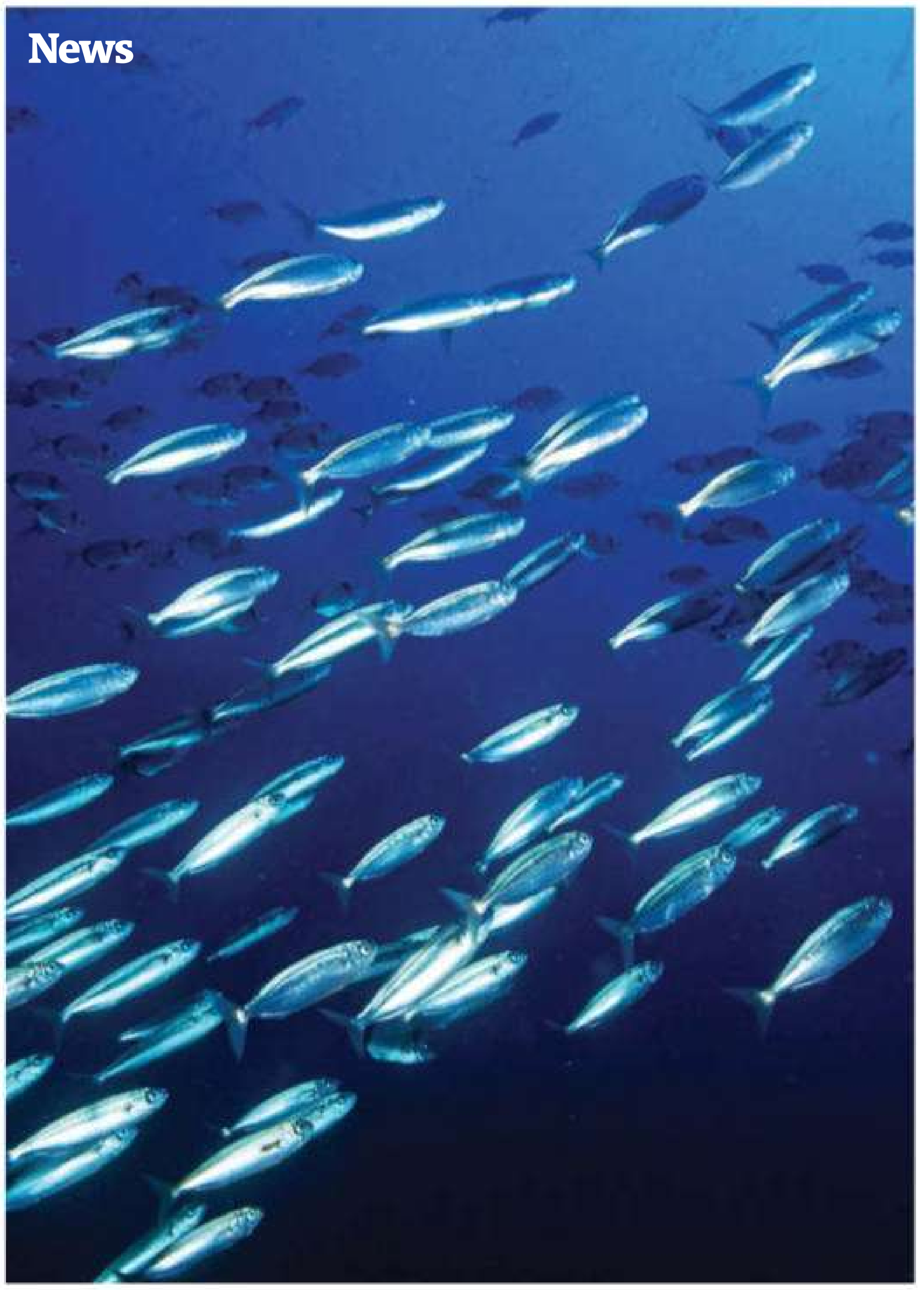

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Phone home? Sam Wong wonders why we haven't heard from aliens

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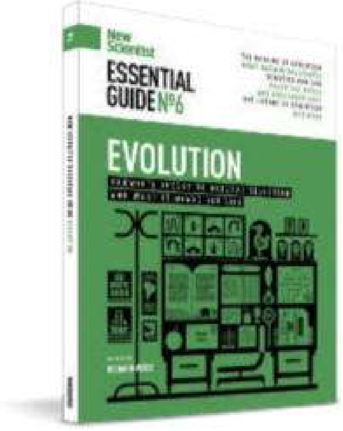
Newsletter

> **"Africa is really big. And when it comes to the study of human evolution, most of it has been neglected"**



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The leader

We must avoid complacency

What is happening in India could occur elsewhere if rising case numbers are ignored

THE situation in India continues to worsen, with more than 20 million cases of covid-19 recorded and health systems overwhelmed. But there is nothing unique about India that means it alone could face such a crisis. Around the world, country after country is being hit by surging coronavirus cases, driven in part by new variants that are harder to control.

The pandemic is accelerating across South America, and cases are rising in many African countries too. In most low and middle-income nations, few people have been vaccinated against the coronavirus, compared with some high-income countries, where high vaccination rates are allowing restrictions to be eased. Add to this the fact that many lower-income countries don't have the medical capacity to deal with a huge new wave, and you have a catastrophe in the making.

There has been much discussion of vaccination in relation to easing India's plight (see page 7). One thing we can say, though, is that vaccines alone won't halt a surge in cases. Chile saw case numbers soar even as it vaccinated nearly half of its population, for instance. In Israel and England, vaccination has been used as a way out of lockdown, with the lockdowns used as the main way to control surging case numbers.

> "So far only one country has managed to vaccinate its way out of a potential new wave"

So far, only one country has managed to vaccinate its way out of a potential new wave of covid-19. In the US, the vaccine roll-out appears to have been ramped up in time to curb a surge due to the B.1.1.7 variant imported from the UK.

The issue is that to reduce the spread of the coronavirus, the majority of a population needs to be fully immunised with a highly effective vaccine. That takes time even with ample vaccine supplies, and India has neither time nor vaccine supplies on its side. In the meantime, another national lockdown, however difficult, seems necessary.

The crisis in India is a warning. Until many more countries have been able to vaccinate most of their populations, what has happened in India could occur elsewhere if rising case numbers are ignored. Those countries must plan for the worst and the global community must be ready to help. ▮

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© 2021 New Scientist Ltd, England. New Scientist is published weekly by New Scientist Ltd. ISSN 0262 4079. New Scientist (Online) ISSN 2059 5387. Registered at the Post Office as a newspaper and printed in England by Precision Colour Printing Ltd

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Global outlook

India crisis: What happens next?

How bad will India's covid-19 crisis get, what can be done to stop it and will it be mirrored elsewhere? **Michael Le Page** and **Clare Wilson** report

Covid-19 patients inside a converted banquet hall in New Delhi

WHILE life in some rich countries begins to return to a semblance of normality, the global coronavirus crisis is far from over. Official case numbers in India have surpassed 20 million and, globally, the week beginning 26 April was the worst since the pandemic began. Worldwide, the number of reported new daily infections hovers around 900,000, although this is a huge underestimate. More than a third of these are in India, where infections are still rising. *New Scientist* looks at what happens next.

How much worse will it get for India?

India's second wave looks set to get a lot worse before it gets better. In terms of the number of people being infected, the outbreak is already by far the worst in the world. Having recorded more than 400,000 cases on 30 April, as *New Scientist* went to press, reported daily cases were hovering around 350,000 and some models have predicted this could pass half a million in May.

Most models suggest that we will see increases in cases until the middle of May and then we will see a decline, says Gautam Menon at Ashoka University in Sonepat, India.

If so, the number of deaths could keep increasing until the end of May. With hospitals already overwhelmed, this would have further devastating consequences.

The US still holds the record for the highest reported daily covid-19 deaths, 4500 on 12 January, and the most reported deaths overall – nearly 600,000. Brazil is second, with 4249 deaths on 8 April and around 400,000 in total.

On 3 May, India reported 3449 new deaths and, so far, it has reported just over 200,000 deaths since the pandemic began. The official figures are thought to greatly underestimate the true number of cases and deaths, however.

In fact, the actual number of daily infections in India could be more than 14 million, according to Christopher Murray at the Institute for Health Metrics and Evaluation (IHME) in Seattle. "The number of infections right now is extraordinarily large," Murray wrote in an IHME analysis on 23 April. "There are more infections happening in India than what occurred globally two weeks ago."

> "There are more infections happening in India than occurred globally two weeks ago"

According to the IHME, the actual number of daily deaths in India is around 8000 and could peak at 13,000 in May, with the total surpassing 900,000 by the end of June.

Other estimates of the death counts are even worse. John Burn-Murdoch at the *Financial Times*

›

has compared local news reports to official numbers and concluded that the actual number is at least 10 times higher.

How does India get out of this crisis?

"The key thing is to lock down the country and stop transmission," says Ravi Gupta at the University of Cambridge.

That is what India did in response to its first wave, imposing a strict country-wide lockdown on 24 March 2020. But the government has been reluctant to impose another lockdown or take other measures. When cases started rising in February, it did nothing, allowing political rallies and religious festivals to continue.

But the issue is complicated. The government gave only 4 hours' notice before the lockdown and many migrant workers were unable to work and afford food or rent. Lots of people are leaving big cities in fear of the same thing happening again, which could be contributing to the spread of the virus in rural regions.

> "It could take until November to vaccinate all adults in India, and the end of May for the over-60s"

Some cities and regions have imposed restrictions. "There is currently a patchwork of local lockdowns, including in the cities and states which have seen recent sharp increases," says Menon. "This should certainly help in breaking the chain of transmission in those locations."

Vaccination is unlikely to help much in the next few weeks. Less than 10 per cent of the 1.4 billion people in India have had at least one dose of a covid-19 vaccine, and it will take many months to get a large proportion of the population vaccinated.

In March, India restricted the export of locally made vaccines. Even if this ban is maintained, science analytics company Airfinity estimates that it would take until November to vaccinate all adults. All over-60s could be vaccinated by the end of May, however, which wouldn't stop transmission, but should help reduce the number of deaths.

According to the IHME, this second wave might already have peaked in terms of the number of cases. So many people have already been infected that the virus may start to run out of hosts.

"It could happen," says Gupta, who thinks the IHME numbers are plausible. But the sheer number of cases suggests that some people infected during the first wave might be being reinfected, he says. "That worries me because it tells me that the things we were worrying about – escape by these viruses – might actually be happening," he says, referring to the potential of some variants to evade the body's immune response. "But we don't know yet."

How long will this wave last?

Nobody knows for sure, but it is likely to be several months before this second wave is over.

India's first wave was protracted, beginning in March 2020, peaking in September and gradually declining until February. At its height, India was reporting just under 100,000 new cases and around 1200 deaths per day.

357,316

Recorded covid-19 cases in India on 3 May

14 million

Suspected number of peak daily covid-19 cases in India

15

The number of mutations in India's "double mutant" variant

What is India's 'double mutant'?

India's "double mutant" coronavirus variant, more accurately known as B.1.617, is a variant of SARS-CoV-2 that is common in India and present in several other countries.

Media reports claim it is the main cause of India's second wave, but this hasn't been formally established. It may be one of several variants playing a role.

Calling it India's double mutant is misleading on two counts. First, B.1.617 has around 15 mutations. Double mutant refers to the fact that it has two mutations of particular concern in the outer spike protein of the virus, which the virus uses to enter cells.

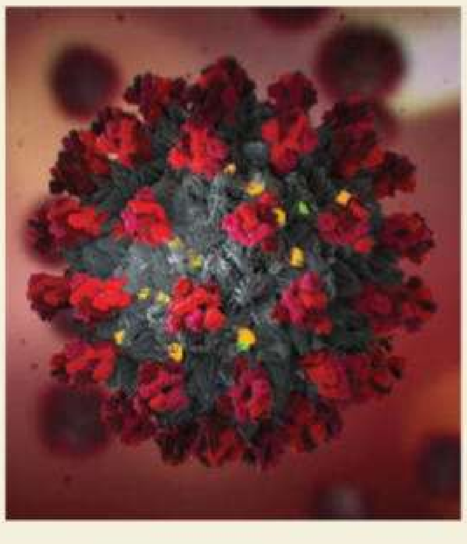
These mutations may make antibodies to older variants or existing vaccines less effective, although initial studies suggest that the Covaxin and Oxford/AstraZeneca vaccines used in India still prevent infection by B.1.617.

Second, the two mutations are not unique to B.1.617. Other variants with both mutations have been found elsewhere.

B.1.617 has reportedly become the most common variant in Maharashtra state, suggesting it is more transmissible than other variants present there. However, in parts of India, other variants are more common.

The number of cases of the B.1.617 variant detected in the UK rose sharply recently, but almost all were in people returning from abroad. Since 23 April, the UK has banned travel from India to try to prevent further imports.

Some B.1.617 viruses have an additional mutation called V382L in the spike protein, often reported as a "triple mutant", but there is no evidence that this variant spreads more readily or is deadlier.



3D rendering of the spike proteins on SARS-CoV-2

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Because this second wave has been allowed to rip through the population in a much less controlled way, case numbers could also come down much more quickly.

“It is hard to say at the moment, but the likelihood is that it will not be too protracted,” says Menon.

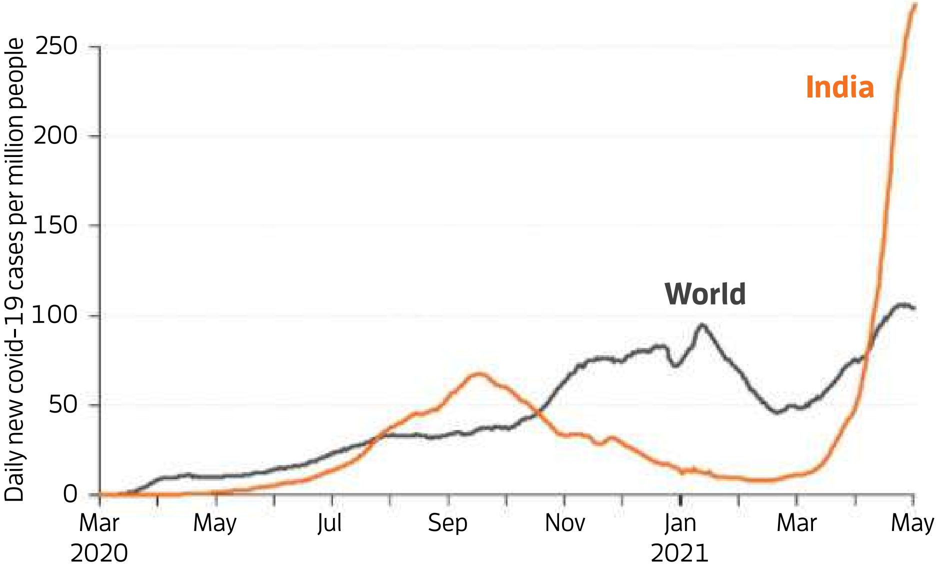
Even so, it will take a while. According to the IHME model, the real number of infections will fall from 14 million per day now to 3 million a day by the beginning of June.

The number of deaths, however, will keep increasing until mid-May and won’t fall below the current level until early June. What actually happens, of course, depends largely on what actions are taken in India.

VIJAY BATE/HINDUSTAN TIMES VIA GETTY IMAGES

People over the age of 45 wait to be vaccinated in Mumbai, India

India’s daily new covid-19 cases are rising rapidly



SOURCE: OUR WORLD IN DATA NUMBERS ARE SEVEN-DAY ROLLING AVERAGES

Could other countries see cases soar in a similar way?

That partly depends on the reasons for why India is experiencing such devastating case numbers, which aren’t yet clear. Many scientists have suggested that new variants of the virus that are more infectious or deadly are to blame. In the north of India, the B.1.1.7 variant that originated in the UK is rampaging. Elsewhere, the new B.1.617 variant, which the media have incorrectly termed the “double mutant”, has become common (see “What is India’s ‘double mutant’?”, left).

Both variants seem to be more transmissible, although it isn’t clear how responsible they are for the change in India’s fortunes, says Gupta.

India’s relaxation of social distancing measures over the past few months is also partly to blame. Politicians, including the prime minister, Narendra Modi, said earlier this year the virus had been defeated, and encouraged mass gatherings. There have also been protests by farmers near Delhi, which has been badly hit in the second wave.

“You can’t use the new [variants] as an excuse for not controlling an epidemic,” says Gupta. “It is because of lax measures, lack of surveillance and then very slow intervention.”

Even events that are held outside can spread the virus when people eat indoors or use public transport, says Michael Head at the University of Southampton, UK. “It was a perfect storm of many large gatherings [without social distancing precautions], in part because political leaders were saying it’s fine to do these things,” he says. “If you give people the perception the pandemic is over, that’s how they will respond.”

> **“It was a perfect storm of many large gatherings and politicians saying it’s fine to do these things”**

As a result, any country where social distancing restrictions ease and vaccination levels are low could experience a similar surge, says Head.

Alongside vaccination numbers, we need to look at what is called the test positivity rate – the share of tests coming back positive – to identify countries at particularly high risk.

Testing helps health services monitor and control the spread of infection, but many people who are infected don’t get tested. They may have no symptoms, they may not wish to self-isolate or there may not be enough tests available. A high test positivity rate suggests there are many people infected who are going undiagnosed and so further spreading the virus.

If a region has a test positivity rate of less than 5 per cent, that is an indicator that its epidemic is under control, according to the World Health Organization.

The UK’s test positivity rate is currently less than 1 per cent, while India’s is about 20 per cent. Other large countries with high test positivity rates and few people vaccinated include Mexico, Argentina and Turkey, says Head. “There could easily be a next India just around the corner,” he says. ▮

Briefing

Vaccine side effects

What side effects can you expect from the covid-19 vaccines and what do they mean? **Clare Wilson** reports

AS GROWING numbers of younger adults get vaccinated against covid-19, social media is awash with conversation about side effects, which appear to be more common in young people. What kind of side effects can people expect, how can they be distinguished from signs of a rare blood clot syndrome, and what do they mean for people's immunity?

What side effects may people experience after a covid-19 vaccine?

All vaccines can cause pain and swelling at the injection site, as well as more widespread, or "systemic", effects. According to the National Health Services in the UK, these can include fever, fatigue, headache, muscle and joint pains, nausea and chills – when people feel cold without apparent cause – and tend to happen in the first day or two after the jab. They shouldn't last longer than a week.

"Having no side effects doesn't mean you haven't built up an immune response"

The impression of covid-19 vaccinators is that between a third and a half of people experience these systemic effects in some form, but most will be mild, says Paul Morgan at Cardiff University in the UK, who is a member of the British Society for Immunology's covid-19 task force.

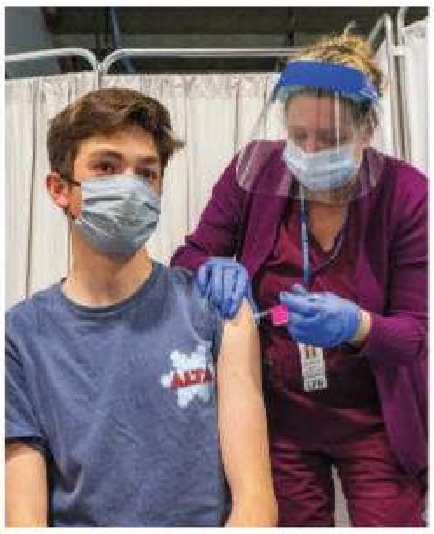
Why do side effects occur?

Most coronavirus vaccines work by forcing the body to make the coronavirus spike protein, which is the part of the virus that allows it to bind to and invade cells. This then triggers an immune response. However, it takes a few days for the body to start producing the spike protein. This means that any immediate side effects you experience are probably a response to other vaccine components, such as the liposome shell used to deliver the spike protein mRNA in the Pfizer/BioNTech jab or the adenovirus that contains spike protein DNA in the Oxford/AstraZeneca one.

Immune cells respond to these unfamiliar substances in the arm muscle by releasing signalling chemicals called cytokines to activate other parts of the immune system. The result is systemic inflammation, leading to aching, tiredness and in some cases a fever.

What are the signs of a dangerous blood clot?

According to advice from the NHS, people who have had the Oxford/AstraZeneca vaccine should consult a doctor if they have a severe headache, leg swelling, abdominal pain or shortness of breath between four days and four weeks later.



A 16-year-old receives the Pfizer/BioNTech vaccine in Massachusetts

JOSEPH PREZIOSO/AFP VIA GETTY IMAGES

A rash that looks like small bruises or bleeding under the skin could also be a sign of low platelets.

But it is important to remember that the risk of adverse side effects from these vaccines is very low. For people under 30, the chance of the Oxford/AstraZeneca vaccine causing clots is a little greater than the risk of severe illness from covid-19. For this reason, several countries have restricted its use in younger people.

Are side effects more common in younger people?

Results from trials of the vaccines from Pfizer/BioNTech, Oxford/AstraZeneca and Moderna suggest that younger adults are more likely to experience injection site and systemic reactions. This could be because older people have a weaker inflammatory response.

Are side effects worse with the Oxford/AstraZeneca vaccine?

One study showed that about three in 10 people reported systemic effects after the Oxford/AstraZeneca jab, compared with about one in 10 with the Pfizer/BioNTech vaccine. But other factors may be responsible, such as the likelihood of reporting side effects.

Do side effects mean you have a stronger immune response?

Morgan says people have great variability in their reactions to vaccines and those who notice no systemic effects have nothing to worry about. People will respond differently to inflammation, for instance, he says, but having no side effects doesn't mean you haven't built an immune response. ▮

Exercise

Lockdown inactivity in England proves long-lasting

Layal Liverpool & Adam Vaughan

MORE than one in four people in England did less exercise in the first lockdown than they would normally and didn't increase it afterwards. The results from the first study of how physical activity changed beyond lockdown suggests that decreased physical activity could worsen obesity levels in the country.

A survey of 36,000 people taking part in the University College London (UCL) COVID-19 Social Study found that 29 per cent decreased their physical activity between March 2020, when the lockdown started, and August.

"It's a sizeable number," says Andrew Steptoe at UCL. "[Although] there were stay-at-home orders, people were encouraged to go out and exercise, but some people didn't. Some people were frightened of catching covid. Some didn't live in the circumstances where they had the opportunity to do this." Steptoe says he was surprised that people weren't more active after restrictions lifted in May 2020.

The research, which hasn't been peer-reviewed, found that 62 per cent of people maintained their old level of physical activity, and just 9 per cent increased it (medRxiv, doi.org/f94t). Steptoe's team had expected to see an urban-rural divide, with people outside cities exercising more as they had more space, but that wasn't the case.

However, people who were older, more educated, richer and lived with other people were more likely to be more active. The team says the decrease in physical activity has immediate and long-term implications for people's physical and mental health.

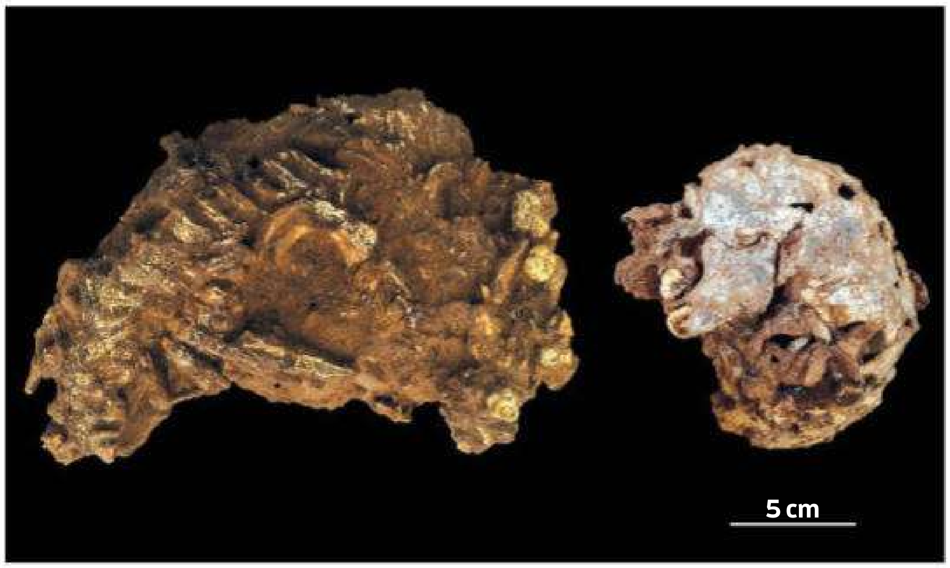
Naveed Sattar at the University of Glasgow, UK, says he has seen a growing number of patients who are struggling with weight gain during the pandemic and says he is worried that this may worsen the epidemic of obesity. ▮

Archaeology

The oldest burial in Africa

3-year-old child from the Middle Stone Age found in a purposefully dug pit

Alison George



MARTINÓN-TORRES, ET AL. 2021

This partial skeleton (left) and skull were discovered in a cave in Kenya

THE oldest known burial in Africa is of a 3-year-old child who died around 78,000 years ago. The discovery sheds light on how people in the region cared for their dead at that time.

In 2017, archaeologists uncovered the top of a bundle of bones in a cave in Kenya called Panga ya Saidi. The remains were so fragile that a block of sediment around the bones was extracted intact and sent to the National Research Centre on Human Evolution (CENIEH) in Spain.

"We didn't know until a year later what was really going on in there," says María Martinón-Torres at CENIEH. "Unexpectedly, that sediment block was holding the body of a child."

The researchers named the child Mtoto, which means "child" in Swahili, and estimate that they lived around 78,300 years ago, making this the oldest deliberate burial found in Africa. "It was a child and someone gave it a farewell," says Martinón-Torres.

Analysis of the sediment surrounding the remains revealed that the child had been placed in a deliberately excavated pit and covered with sediment from the cave floor. They had been placed on their side with their legs drawn up to their chest. As the body decayed, most of Mtoto's bones stayed in position, but the collarbone and top two ribs were displaced in a way typical of a body tightly bound in a shroud. And Mtoto's head had the characteristic tilt of a corpse whose head was placed on a cushion. This points to a deliberate burial (*Nature*, DOI: 10.1038/s41586-021-03457-8).

"From these little pieces of bone that were preserved, the work that we have done has allowed us to reconstruct the human behaviour surrounding the moment the body was put in the pit," says Francesco d'Errico at the University of Bordeaux, France.

The discovery of any ancient human remains in Africa is big news in itself. "We have huge temporal and spatial gaps, so this discovery is extremely important," says Eleanor Scerri at the Max Planck Institute for the Science of Human History in Germany, who wasn't involved in the research.

Mtoto's burial took place in the Middle Stone Age, which spans from roughly 300,000 to 30,000 years ago, when a suite of modern human innovations developed in Africa. Early evidence of burials in Africa is rare. No buried adults have been found from this period, although the burial of an infant in Border cave in South Africa dates to around 74,000 years ago, and the burial of a child who was about 9 years old in Taramsa Hill, Egypt, dates to around 69,000 years ago.

This lack of burials shows the mortuary practices of modern humans in Africa differed from those of Neanderthals and modern humans in Eurasia, who, from about 120,000 years ago, commonly buried their dead. "That is a quite a paradox," says d'Errico. "In Africa, where we have the origin of symbolic behaviour in the form of beads and abstract engravings, these modern humans wait quite long to make primary burials." ▮

Animal behaviour

Female black widow spider mates with and eats many males

A SOUTH American black widow spider starts biting, wrapping up and eating a willing partner before they have finished mating. Then, in a surprising twist, she mates with and consumes another male.

The discovery was made by Luciana Baruffaldi and Maydianne Andrade at the University of Toronto in Scarborough, Canada, after they collected and studied dozens of wild juvenile mirabilis widow spiders (*Latrodectus mirabilis*) in Uruguay.

Once the arachnids had reached sexual maturity, the scientists placed females in individual "mating arena" cages, where each built a web. The researchers then added a male to each arena.

All 20 females accepted males that "courted" them by vibrating the web. During copulation, 14 of the females cannibalised the males, which put up no resistance.

In a second lab experiment, the researchers discovered that most females that had mated with and eaten a male within the past month were willing to mate with a second male – before eating him as well (*Behavioural Processes*, doi.org/f87k). It is a bit of a puzzle why males would sacrifice themselves in this way when it doesn't necessarily guarantee they will father the female's offspring.

KEN JONES/UTSC

The mirabilis widow spider (*Latrodectus mirabilis*)

The males' passive acceptance of their fate suggests they must find some benefits to sexual cannibalism, says Baruffaldi. "They're just there like, 'Hello, I'm here, eat me if you want'," she says.

It is possible that males consider self-sacrifice worth it even if they have a low probability of siring offspring because the alternative is to sire no offspring at all.

"A lot of males get killed trying to find a female," says Baruffaldi. "So maybe when they do find one, they're like, 'OK, this is my only chance,' and they just invest everything they've got." ▮

Christa Lesté-Lasserre

Environment

Birthplace of the Anthropocene

Humanity has left a geological mark on Earth – now we need to decide where it begins

Adam Vaughan

A BAY in south-west Japan could become the place on Earth used to officially establish the start of the Anthropocene, a new epoch shaped by human impact.

Thanks to research showing a decline in sardine scales due to fishing and other evidence revealing our growing influence on the planet, Beppu Bay has now formally joined 10 other sites being considered by researchers trying to find the best candidate for a "golden spike", a clear signal in Earth's geological record that can designate this epoch.

In 2016, scientists on the Anthropocene Working Group (AWG) voted to define a new epoch starting around the middle of the 20th century, on the grounds that humanity's nuclear weapons testing, fossil fuel burning, plastic pollution and other activities were of sufficient scale to push the world into a new geological age.

But the Anthropocene remains just an idea rather than an official epoch until approved by the International Commission on Stratigraphy, the arbiter of geological timescales.

Gaining approval will require AWG researchers to provide evidence from one location with enough markers to demonstrate the start of the Anthropocene. Radionuclides from nuclear weapons tests are thought to be the most obvious marker. However, the group is seeking a location with multiple indicators to serve as the golden spike, or the so-called global boundary stratotype section and point (GSSP).

An ice core from Greenland marks the GSSP for the end of previous epoch, the Pleistocene, and the start of the current one, the Holocene.

Now, a flurry of research from Japan means Beppu Bay is the 11th potential GSSP, up against sites such as an Italian cave, a Chinese lake and a coral reef off Australia. "Beppu Bay is a spawning site for sardines in the western Pacific and researchers have managed to match very nicely the density of sardine scales in the sediment core with written records of sardine catches in Japan over many centuries," says Colin Waters at the University of Leicester, UK.

Simon Turner at University College London says there are a variety of records showing how humans have influenced the sediment record in the bay, notably the acceleration of the use of PCB chemicals post-1950 and the presence of caesium-137 from nuclear weapons tests. Analysis of plutonium isotopes at the bottom of the bay could provide more evidence, he says.

Speaking at the virtual European Geosciences Union general assembly on 28 April, Turner gave an update on the other 10 potential GSSP locations. Teams working on sediment cores from the Baltic Sea and from Searsville Lake in the San Francisco Bay area are two of the furthest ahead for completing work on Anthropocene markers.

He says geologists are "on track" to propose a start for the Anthropocene based on one of the 11 sites by next year. ▮

Fewer sardine scales in sediment could mark the start of the Anthropocene

LISA TOP/ALAMY

Materials science

Your finger can feel the change of one atom in a material

THE human fingertip can distinguish between materials that have minuscule chemical differences – even a substitution as small as a single atom.

Generally, what we feel with our fingers are physical bumps in a material's surface structure. Charles Dhong at the University of Delaware and his colleagues set out to find whether it would be possible to feel a chemical difference in which the internal molecular structures of two materials slightly vary but their surfaces are equally smooth.

They did this by taking a silicon wafer and attaching a layer of a simple compound that was just one molecule thick. They tested several compounds, each only slightly different from the others.

Out of six pairs of compounds, human testers could distinguish between three. With one pair, where the team only substituted a single carbon atom for a nitrogen one, the testers could tell the two apart with 68 per cent accuracy (*Soft Matter*, doi.org/f9mc).

"When we make our samples, physically they're almost identical, the differences are on a sub-nanometre scale," says Dhong. "But when test subjects felt them, some people said that some felt a little gritty and other ones were more pleasant and velvety."

The chemical difference between the two compounds that the testers were best able to tell apart caused a slight change in how much friction they felt when running a finger over them. This alteration wasn't due to bumps in each material, but rather the way their molecules fitted together.

Dhong says this could be useful for people with visual impairments or to make textures in virtual reality that feel real. "If you wanted to create a texture that feels like running your hand across really nice paper or soft velvet or a wooden table, how can you do that with something like a screen? This gives us a lot more options to really expand this toolbox," says Dhong. ▮

Leah Crane

"It may be possible to create a texture on a screen like running your hand across velvet or a wooden table"

Pregnancy

Negative events before birth increase mental health risk

Krista Charles

CHILDREN who experienced multiple negative events before birth, such as exposure to alcohol or pre-eclampsia, are at higher risk of experiencing poor mental health a decade later.

Joshua Roffman at Harvard Medical School in Boston and his colleagues asked the parents of almost 10,000 children aged 9 or 10 years whether the children had experienced a range of negative events before birth. They also used a standard child behaviour questionnaire to identify children with mental health issues, including anxiety and depression.

The negative events the researchers looked at included exposure to alcohol, tobacco or marijuana both before and after the pregnancy was known, pregnancy complications and birth complications. They also looked at unplanned pregnancies.

These have all previously been identified as individual mental health risks to children, but the team found that they have a compounding effect – children who had experienced the most events were at highest risk (*PLoS One*, doi.org/f9bs).

"The risk increased relatively steeply as the number of exposures went up, so while children who had no such exposures only had about a 7 per cent risk of clinically significant symptoms at that age, those with four or more exposures had a 29 per cent risk," says Roffman.

This could help identify families and children who may need more support, says Helen Dodd at the University of Reading, UK. "Some of it is about supporting women who are pregnant to prevent big exposures and some of it is also about using these exposures as ways of working out who might need the most support during those early years."

Fossils

Billion-year-old microbe took steps towards internal organs

Michael Marshall

A TINY organism that lived a billion years ago had two different cell types, one forming its core and another its outer "skin". It may have been one of the first life forms built that way, making it a crucial step towards modern organisms like animals that have a skin that is distinct from the cells inside the body.

"This fossil clearly is multicellular, with two different types of cell," says Charles Wellman at the University of Sheffield, UK. While organisms made of multiple cells were known to have existed for hundreds of millions of years before this, he says, having such an ancient one with recognisable cell types is new.

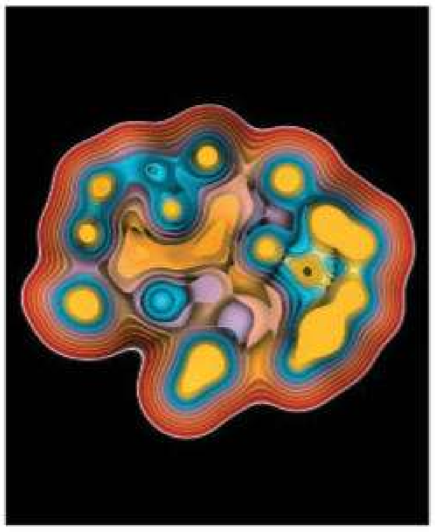
The first organisms were single-celled – as many life forms still are today – but, through the process of evolution, some began joining up to form larger, multicellular organisms.

"It's actually surprisingly common," says Emily Mitchell at the University of Cambridge.

2.1

billion years ago is when we see the first hints of multicellular life

Multicellularity evolved independently several times in different groups. On current evidence, it is possible that the first multicellular organisms appeared more than 2 billion years ago. But it wasn't until about 600 million years ago that we see the first convincing fossil evidence of complex animal life, suggesting there was a huge time lag before multicellular organisms gained the sort of biological complexity typical of animals.


BENNU PHOENIX/ALAMY

The microfossils Wellman and his colleagues studied may help us understand how multicellular life became more complex. The fossils were preserved in rocks in north-west Scotland that are about 1 billion years old and that formed in an ancient freshwater lake.

The microfossils are unlike any so far discovered in billion-year-old rocks elsewhere in the world. In recognition of this, the researchers placed them in a new species, which they named *Bicellum brasieri*. Each *B. brasieri* was a clump of a few dozen cells just tens of micrometres across. There was a central ball of tightly packed oval cells, surrounded by an outer layer of sausage-shaped cells (*Current Biology*, doi.org/f9bt).

Some of the fossils only had the central ball. The team suggests that these show the organism in a larval stage. "The cells keep dividing to form this ball of cells, and then different cells form in it that elongate and these appear to migrate to the outside and form an outer layer," says Wellman.

The team believes the two cell types might be explained by basic physics. The late biologist Malcolm Steinberg argued that if some cells stick together better than others, that will be enough to generate quite complex structures, an idea he called the differential adhesion hypothesis. For Wellman, the structure of *B. brasieri* is compatible with this idea.

Life has evolved to be multicellular many times

B. brasieri wasn't a true animal, emphasises Wellman. "There's a long, long way to go until you get real animals," he says. But it probably belonged to the larger group from which animals arose. "It's telling us about the really early events in that lineage."

"Studies like this show how some of the early steps towards complex multicellularity may have occurred," says Jennifer Hoyal Cuthill at the University of Essex, UK. "Groups of cells with two distinct types may have been a key step on the way to the many structurally differentiated cells and, later, tissues that enable animal-level complexity."

For Mitchell, the "million-dollar question" is why it took multicellular organisms hundreds of millions of years to give rise to complex animals like sponges, jellies and worms. For many years, it was assumed that an increase in oxygen levels around 550 million years ago enabled animals to develop. In recent years, however, evidence has emerged that ancient animal groups like sponges can survive at low oxygen concentrations – and that oxygen levels only climbed after the first animals had appeared.

"It couldn't have been the perturbation in the atmosphere that caused animals," says Mitchell, so there must be another explanation.

Green energy

Car batteries could provide a new use for driftwood

Bas Den Hond

DRIFTWOOD collected from rivers could be recycled for use in future electric car batteries.

The remains of trees provide many benefits to ecosystems in rivers and oceans, but driftwood is a nuisance for dam operators. For example, each year, 1300 tonnes of wood have to be pulled out of a section of the Rhône river near the the Génissiat hydroelectric plant in France so as not to interfere with it, says Abdullah Qatarneh, formerly at the IHE Delft Institute for Water Education in the Netherlands.

The wood is usually burned or ends up in landfill, but Qatarneh and his colleagues have found that it makes an excellent raw material for a form of carbon used in a battery technology that is being considered for use in electric cars.

The researchers treated driftwood with a process called hydrothermal carbonisation, which involves submerging it in water and subjecting it to pressure and 200°C heat until it turns into a carbon-rich solid called hydrochar.

They then baked the hydrochar at 1400°C until it turned into a material called hard carbon and tested its performance in sodium-ion batteries, which use it as their anode material. The batteries worked well, Qatarneh told the virtual annual conference of the European Geophysics Union on 27 April.

Electric vehicles generally run on lithium-ion batteries at the moment, but lithium is expensive and can be environmentally damaging to mine. Sodium-ion batteries are seen by some as a better alternative, but hard carbon for these batteries is currently produced using fossil fuels.

Driftwood could be a better option – the wood of the Génissiat dam alone could produce enough anode material for several thousand electric cars each year, says Qatarneh. ▮

Evolution

Yeast species has strange form of sexual reproduction

Michael Marshall

A SPECIES of yeast has weird sex. While most organisms use sex to reshuffle their genes and create offspring that are genetically different from their parents, this one goes to extreme lengths to avoid recombining its DNA.

The yeast, called *Saccharomycodes ludwigii*, illustrates a problem that all sexually reproducing species face: while sex has evolutionary benefits, it also has costs. In some circumstances, reshuffling genes can produce individuals that can't survive, so it is better not to do it too much.

10

strains of *Saccharomycodes ludwigii* don't shuffle their genes

"This species is an extreme case," says Michael Knop at Heidelberg University in Germany. Knop and his colleagues have spent more than a decade studying *S. ludwigii*. Like other yeasts, it is a single-celled fungus and can reproduce sexually.

Yeasts do this through a process called meiosis: an individual species starts out with two copies of every chromosome, and therefore two copies of every gene. Each "adult" cell then shuffles genes between its chromosomes through a process called recombination, before producing daughter cells that carry just one copy of each chromosome.

Because of the recombination, the chromosomes that these daughter cells carry are genetically distinct from those present in the adult – and so when two such daughter cells fuse together to form offspring with two copies of every chromosome, these offspring will also be genetically distinct from the original adults.

But this isn't the case in *S. ludwigii*. Knop and his team found that this yeast hardly ever performs recombination. They sequenced parent and offspring yeast and couldn't find any pieces of chromosome that had been swapped. This result held true when the researchers examined 10 different strains of the species, suggesting that it has behaved this way for a long time (bioRxiv, doi.org/f9jj).

It isn't that *S. ludwigii* can't perform recombination – the researchers found that it still has the majority of the genes required to do so.

"There's a pressure to keep [recombination rates] so low that it's very rarely occurring, but it is not trapped in a situation where it can't do it any more," says Knop.

"It's great to have learned more about the unusual biology of a fascinating system," says Maurine Neiman at the University of Iowa in Iowa City.

Although it isn't yet clear why the yeast doesn't shuffle its DNA, the cause may have been the deletion of a gene called *MER1*, which is involved in recombination but isn't entirely essential. Knop suspects this was an accident: it may have solved a problem that the species was experiencing, but left it with reduced recombination.

Yeasts start out with two copies of each chromosome

SCIEPRO/SCIENCE PHOTO LIBRARY

For Neiman, *S. ludwigii* fits into a larger picture. "All sorts of organisms have evolved ways to get at least some of the benefits of sex without all the costs," she says. Organisms aren't simply sexual or asexual, she says: there is a spectrum.

There are many reasons why organisms might limit recombination, says Neiman. "You're breaking up genes that work well together, without any predictions regarding how they're going to do in their new combination." So while recombination can produce beneficial combinations of genes, it can also produce harmful ones that mean some offspring don't survive.

This risk may be worthwhile in highly changeable environments, but not in stable ones. However, Neiman says it is hard to pin down which aspects of the environment are most important.

She points to a 1995 paper titled "Is a little bit of sex as good as a lot?" that argued many species would do best if they only rarely recombined their genes. But not all organisms have the molecular machinery to exert that kind of precise control, hence species like humans where the mixing of sperm and egg is a lottery. "These yeast," says Neiman, "might have gotten it exactly right." ▮

Archaeology

Ancient Arabian monuments

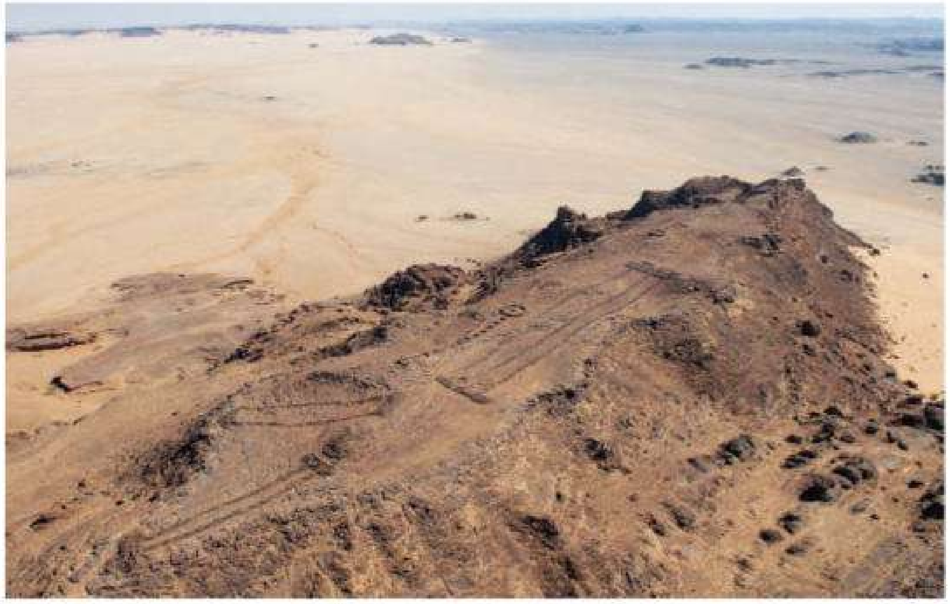
The 1000 structures may have been used in rituals and predate Stonehenge

Ibrahim Sawal

A VAST site in north-west Saudi Arabia is home to 1000 structures that seem to date back more than 7000 years, making them older than the Egyptian pyramids and Stonehenge in the UK.

Named after the Arabic word for rectangle, mustatil structures were first discovered in the 1970s, but received little attention from researchers at the time. Hugh Thomas at the University of Western Australia in Perth and his team wanted to learn more about them, and embarked on the largest investigation of the structures to date.

Using helicopters to fly over north-west Saudi Arabia and then following up with ground explorations, the researchers found more than 1000 mustatils across 200,000 square kilometres – twice as many as were previously thought to exist in this area.



AAKSA AND ROYAL COMMISSION FOR ALULA

Mustatils have long walls surrounding a central, rectangular courtyard

Made from piled-up blocks of sandstone, some of which weighed more than 500 kilograms, the mustatils ranged from 20 metres to more than 600 metres in length, but their walls stood only 1.2 metres high. "It's not designed to keep anything in, but to demarcate the space that is clearly an area that needs to be isolated," says Thomas.

In a typical mustatil, long walls surround a central courtyard, with a distinctive rubble platform, or "head", at one end and entryways at the opposite end. Excavations at one mustatil showed that the centre of the head contained a chamber within which there were fragments of cattle horns and skulls. The cattle fragments may have been presented as offerings, suggesting mustatils may have been used for rituals.

Radiocarbon dating of the skulls shows that they date to between 5000 and 5300 BC, hinting when this particular mustatil was in use – and maybe when the others were too. If so, the monuments would together form the earliest large-scale, ritual landscape anywhere in the world, predating Stonehenge by more than 2500 years (*Antiquity*, doi.org/f9d2).

"This could completely rewrite our understanding of cults in this area at this time," says team member Melissa Kennedy, also at the University of Western Australia.

There may have been a relationship between the construction of mustatils and the environment. They were built during the Holocene Humid Phase – a period between 8000 and 4000 BC when Arabia and parts of Africa were wetter, and what are now deserts were grasslands. But droughts were still common, and Kennedy says it is possible that cattle were herded and used as offerings to the gods to protect the land from the changing climate.

"The mustatils themselves are probably associated with an annual or generational coming together of people who would normally be out with their herds and cattle," says Gary Rollefson at Whitman College in Walla Walla, Washington, suggesting that these rituals were important for bringing communities together. ▮

Physics

Frigid molecules act as a single quantum object

A FROZEN cloud of molecules that share the same quantum state and behave as if they were a single entity has been created for the first time.

Cheng Chin at the University of Chicago and his colleagues formed a Bose-Einstein condensate (BEC) from thousands of molecules of caesium. They did this by using lasers to remove their energy and cool them to near absolute zero.

BECs are often called the fifth state of matter, after solids, liquids, gases and plasmas. Their particles share the same quantum properties as each other. Chin says this is the ideal initial condition for many experiments, as it removes a lot of variables. "They all work together, they all work in the same way. What they are going to do next, they'll be doing that together. Essentially, it's a kind of giant molecule," he says.

Scientists have been creating BECs with atoms since the 1990s, but putting molecules into this quantum state has proved harder. "Eventually you run out of ideas [for] how to get colder," says Chin.

Instead, the team took a different approach, starting with a single layer of atoms in a BEC and using a magnetic field to induce pairs of atoms to form molecules while still in the BEC state. These molecules remained stable at just 10 nanokelvin, which is fractionally above absolute zero. The team used a wide and very thin laser beam to hold the molecules in place (*Nature*, doi.org/f9br).

"This could pave the way to discovering new materials, such as room-temperature superconductors"

"They've taken something that's been around for maybe 25 years with atoms to the next level. The level of complexity is so much greater," says Peter Krüger at the University of Sussex, UK.

He believes the breakthrough will open the door to research that could lead to materials with long-sought-after properties, such as practical room-temperature superconductors. Superconductors have no electrical resistance, but have so far only worked at extremely low temperatures or at impractically high pressures. ▮

Matthew Sparkes

Analysis Space exploration

Battle of the billionaires Elon Musk's SpaceX has won a NASA contract to land humans on the moon. Do his rivals, including Jeff Bezos, have cause to complain, asks Leah Crane

SPACEX is going to the moon, and its competitors are complaining. On 16 April, NASA announced that it had selected Elon Musk's space-flight company to build the lunar lander that will take humans to the moon's surface as part of its Artemis programme.

SpaceX beat out two rivals that hoped to secure the $2.9 billion contract – defence firm Dynetics and private space-flight company Blue Origin – both of which have now filed complaints with the US government alleging that the selection process was unfair.

Experts in the space community had expected NASA to select two of the three finalists vying for the contract to continue working on their landers, as it did with the capsules that were developed to shuttle astronauts back and forth to the International Space Station (ISS). The reasoning behind this is twofold: it encourages competition in the space industry and it gives NASA a backup plan in case one of the projects doesn't work.

Only one winner

But NASA barely had enough money to hire one firm to build a moon lander, let alone two. It only managed to do so by renegotiating its payment schedule with SpaceX, which submitted a plan that was less than half as expensive as those of the other two firms. In NASA's assessments of each company's management and the technical plans in each proposal, SpaceX was rated higher overall than its competitors.

But Blue Origin, led by Jeff Bezos, took issue with the decision. A statement from the company said: "NASA has executed a flawed acquisition for the Human Landing System program and moved the goalposts at the last minute. In NASA's own words, it has made a 'high risk' selection. Their decision eliminates opportunities for competition, significantly narrows the supply base, and not only delays, but also endangers America's return to the Moon."

PABLO MARTINEZ MONSIVAIS/AP/SHUTTERSTOCK

JOHN RAOUX/AP/SHUTTERSTOCK

Jeff Bezos (left) and Elon Musk (right) are two of the richest men in the world, and they both own private space-flight firms

Dynetics also released a statement saying it "has issues and concerns with several aspects of the acquisition process as well as elements of NASA's technical evaluation", and it has filed a protest with the US Government Accountability Office to address them.

After the protests were filed, Musk tweeted poking fun at the fact that Blue Origin hasn't sent a rocket into orbit yet – all of the company's flights have been suborbital so far. In contrast, SpaceX has already sent its Falcon 9 and Falcon Heavy rockets into orbit 117 times. It has flown humans to the ISS three times, while the other firm selected for that programme, Boeing, has yet to send even a test capsule without a crew to the station successfully.

The craft that SpaceX is developing for NASA's lunar landings is a modified version of its Starship rocket, prototypes of which are being tested in Florida regularly.

All of this is to say that without the budget to select two lunar landers, SpaceX seems to be the obvious choice. While it may not have the historical expertise of the team of major space-flight companies that Blue Origin has assembled, its more recent accomplishments demonstrate that the firm is doing just fine without recruiting others to come in and help.

$2.9bn

Value of SpaceX's contract with NASA for a crewed lunar lander

Regardless of scuffles between two billionaires, someone will have to land humans on the moon for the first time since the final Apollo mission in 1972, and it is pretty clear that Musk is determined to win out. ■

Health

A baby's first stool reveals risk of allergies

Clare Wilson

CHILDREN could be set on a path to developing allergies before they are born. Analysis of a baby's first stool, known as meconium, shows that those with a lower diversity of biochemicals or gut bacteria are linked with a higher risk of allergies and other conditions.

Allergic conditions such as food allergies, hay fever, asthma and eczema are caused by the immune system overreacting to harmless compounds in the environment. Many studies have found links between such immune system reactivity and a lower diversity of gut bacteria, or microbiome. One idea is that a diverse ecosystem of beneficial bacteria helps to "train" the developing immune system to tolerate non-harmful compounds.

Charisse Petersen at the University of British Columbia in Canada and her colleagues analysed the meconium of 100 babies. Meconium isn't normal faeces, but a mixture of substances that entered the baby's mouth in late pregnancy, such as amniotic fluid, skin cells and substances made by the baby's skin.

Chemically, it includes a range of fatty molecules, amino acids and other compounds from the mother's diet. "Meconium is kind of a time capsule because it contains all of the molecules that the baby was exposed to," says Petersen.

Most allergic conditions develop in later childhood, so to get results when the infants were 1 year old, the team did a skin test to measure the immune system's reactivity.

The quarter of the group with the most chemically diverse meconium had half the risk of an overreactive immune system, compared with the quarter who had the least variable meconium. There was a similar-sized link between diverse gut bacteria in the meconium and later immune reactivity (*Cell Reports Medicine*, doi.org/f9f5). ■

Cancer

'Smart' immune cells kill tumours and stop them regrowing in mice

Michael Le Page

IMMUNE cells programmed to attack tumours in a smarter way have shrunk brain and ovarian tumours in mice studies where simpler engineered cells failed.

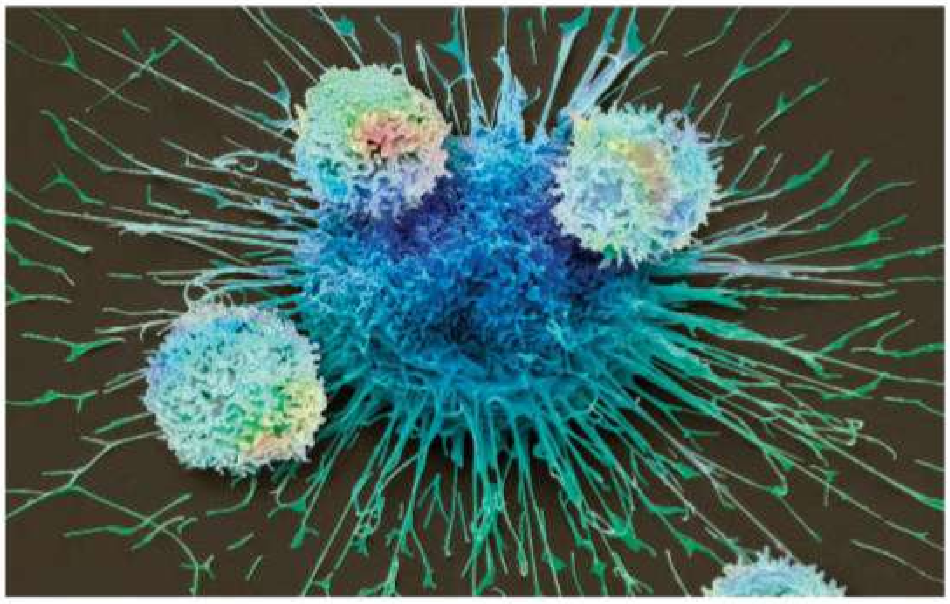
"We have more control over what the cell does when it reaches the disease site," says Kole Roybal at the University of California, San Francisco. "We can really program in very specific functions."

Our bodies naturally kill many nascent cancers, but sometimes immune cells called T-cells don't recognise cancerous cells. One solution is to genetically engineer T-cells to produce a receptor that helps them target a specific protein on the surface of the cancer cells. These are called CAR T-cells, where CAR stands for chimeric antigen receptor.

CAR-T therapies have resulted in successful treatment, leading the US to approve two forms in 2017. But the approach has only been effective against blood cancers such as leukaemia, not against solid tumours. And it can have very serious – even fatal – side effects if the T-cells kill off non-cancerous cells that carry the target protein.

These problems are related. One of the reasons why CAR-T therapies don't work for solid tumours is that not all cells in such tumours express a single, unique protein, says Roybal. His team has developed a new type of receptor protein that works in a different way. Instead of triggering an attack, these T-cell receptors switch on any desired gene or genes when they recognise a target protein.

T-cells of the immune system attack a cancer cell



STEVE GSCHMEISSNER/SCIENCE PHOTO LIBRARY

The team engineered a receptor to recognise a protein specific to some cells in brain tumours called glioblastomas. On detecting it, the receptor activates a gene for a CAR-T receptor that targets a protein found on a wider range of tumour cells and on healthy cells. Crucially, the killing effect is limited to tumour environments where both proteins are present: if the engineered cells leave the tumour, the CAR-T gene switches off again.

In tests in mice, these smart CAR T-cells shrunk glioblastomas and stopped their recurrence where conventional CAR-T therapies didn't work or failed to prevent regrowth (*Science Translational Medicine*, doi.org/f9cr). A separate animal study had similar results for mesotheliomas and ovarian cancers (*Science Translational Medicine*, doi.org/f9dt).

Standard CAR T-cells seem to become exhausted relatively quickly and die off, says Roybal. The smart CAR T-cells persisted for longer in the body, which is key to preventing recurrence, he says.

Donald O'Rourke at the University of Pennsylvania says the approach is creative, but might be too complex. "I don't think it's going to be a panacea for solid tumours, to be honest," he says.

Roybal's team is preparing the therapies used in mice for human trials, which could take a few years. In these, immune cells will be removed, genetically engineered and replaced in the body. In the longer term, it may be possible to treat people using "off-the-shelf" cells, greatly cutting costs. ▮

Environment

Third UK lockdown didn't cut as much air pollution as the first

AIR pollution fell by only 28 per cent during the most recent covid-19 lockdowns across the UK compared with a halving in the first lockdown.

The difference is probably explained by increased air pollution from gas boilers as people worked from home and tried to keep warm during winter, says Rhianna Evans at the University of York, UK, who led the work, which looked at levels of the toxic gas nitrogen dioxide (NO_2).

"Covid has provided us with a glimpse into the future of air pollution," says Evans. The UK's NO_2 pollution from cars and lorries is due to fall in coming years due to electric vehicle take-up, but increased remote working will make home contributions more important. Evans and her colleagues examined data from 30 air pollution monitoring sites across the UK to build a representative picture of NO_2 and ozone levels during covid-19 restrictions around the country.

During both the March-May 2020 lockdown across the UK and the period between January and March 2021 – which aligned with lockdown in England, although lockdowns in Scotland, Wales and Northern Ireland lasted longer – traffic was down about 70 per cent and the level of restrictions was similar.

Yet NO_2 emissions fell nearly twice as much during the 2020 lockdown as they did during the 2021 lockdown. In fact, during 2020, air pollution in the UK fell to its lowest levels in decades. Evans says it is likely that home gas boilers offset the savings in the winter of 2021. This work was presented at a meeting of the European Geosciences Union on 27 April.

"Covid-19 lockdowns have provided us with a glimpse into the future of air pollution"

One side effect of the reduction in NO_2 was an average 21 per cent increase in ozone during the first lockdown, because the amount of NO_2 in the air plays a role in ozone formation. Evans says that makes a case to gather more data with ozone sensors, as the pollutant isn't monitored as comprehensively as NO_2. ▮

Adam Vaughan

OCTAVIO CAMPOS SALLES/ALAMY

Archaeology

Amazon exodus may have begun before colonisation

FOSSIL pollen records hint at a surge of regrowth in Amazon forests centuries before Europeans arrived in South America. This may mean Indigenous peoples were leaving the region at that time.

Following European colonisation in the mid-16th century, millions of Indigenous people lost their lives in the face of unfamiliar disease, slavery and warfare in an event known as The Great Dying of the Indigenous Peoples of the Americas.

Previous studies have shown a dip in carbon dioxide levels in the region in 1610, known as the Orbis spike. This has been associated with the population decline after Europeans arrived, as forests regrew on land previously inhabited by Indigenous people.

But the pollen record suggests regrowth in this region happened earlier. Mark Bush at the Florida Institute of Technology and his team analysed pollen in sediment from 39 lakes in the Amazon, in Brazil, Peru, Ecuador and Bolivia.

They found that forest regrowth in the Amazon basin may have begun around 300 to 600 years before the Orbis spike. They didn't see a pattern of reforestation in the fossil records between 1550 and 1750, following European colonisation (*Science*, doi.org/f9ds). This suggests that Indigenous people were abandoning land hundreds of years before Europeans arrived, says Bush.

Eduardo Góes Neves at the University of São Paulo in Brazil remains unconvinced of this, as it fails to explain the significant drop in CO_2 after the arrival of the Europeans. **Karina Shah**

Evolution

Distant mice adapted to cold in same way

ON OPPOSITE sides of North America, house mice have similar adaptations to cold climates, and have independently evolved changes to genes that drive related behaviours and hardiness.

House mice (*Mus musculus domesticus*) came to the Americas more than 200 years ago and have since expanded into climates quite different to their original temperate European home.

To find out how these mice have adapted, Michael Nachman at the University of California, Berkeley, and his team collected 50 mice from locations in western North America ranging from Arizona in the US to Alberta, Canada. The team analysed DNA from these wild mice and kept some to breed lab populations, comparing these western mice with those from a previous study on mice from the eastern side of the US, ranging from Florida to New York.

The mice were most closely related to those on their side of the continent, suggesting the two groups went north independently after spreading along a southern route, says Nachman. Yet the lab-reared mice from Alberta and New York were physically similar: both were bigger than southern mice and made larger nests, which are factors in combating the cold.

Nachman was surprised that the nest style was genetically encoded after a few hundred generations. "Even at room temperature in a comfy lab… the mice from Canada build a bigger nest than the mice from Arizona," he says.

The western and eastern mice in cold climates shared changes in 16 genes, many involved with body temperature regulation. But they also had regional adaptations, in colour and hydration regulation, which may be due to differences in soil colour and rainfall between west and east (*PLoS Genetics*, doi.org/f9f8). **Jake Buehler**

Solar system

Venus finally reveals some inner secrets

THE core of Venus is about 7000 kilometres across, roughly the same size as Earth's. This is the first observation-based estimate.

Studying Venus is hard as its atmosphere hides the surface. As such, radar and other specialist techniques are required to probe beneath its abundant clouds.

Jean-Luc Margot at the University of California, Los Angeles, and his team examined Venus from 2006 to 2020, using the Goldstone Solar System Radar in California to hit the planet with radio waves. They then used both this and the Green Bank Telescope in West Virginia to track the echoes of the waves as they bounced back to Earth, a technique called radar speckle tracking.

This allowed them to measure changes in Venus's motion. They found its day, roughly equal to 243 Earth days, fluctuated by up to 21 minutes over the 15 years of observation. They also found that Venus wobbled slightly in a way that their calculations suggest would repeat every 29,000 years.

While the latter is the result of the sun's pull, the main factor behind the former is Venus's thick atmosphere, which pushes and pulls the surface. But the team suspects that the core of the planet plays a part, and used the data to calculate that a 7000-km-diameter core can explain the fluctuations (*Nature Astronomy*, doi.org/f9fv). **Jonathan O'Callaghan**

NASA/JPL-CALTECH

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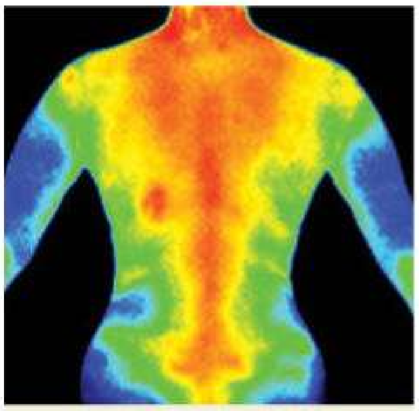
Really brief



ANITAVDB/GETTY IMAGES

Wristband powers LED with body heat

A wearable wristband containing a thermoelectric generator can convert body heat into enough electricity to light up an LED. The device produces power by exploiting the difference between body temperature and room temperature (*Cell Reports Physical Science*, doi.org/f9hk).

Honeybees stress over minor parasite

European honeybees (*Apis mellifera*) release a stress hormone in response to infection by a relatively minor parasite, *Nosema ceranae*. In doing so, they may actually upset a hive's social harmony. Researchers say that this may be a factor in colony collapse (*Royal Society Open Science*, doi.org/f9bq).

Wild horses dig wells in the desert

Feral horses and donkeys in the Sonoran desert in Arizona dig their own wells, providing a water source for themselves and other animals and boosting biodiversity in the area. The wells are up to 2 metres deep, and researchers saw 57 other vertebrate species drink from them (*Science*, doi.org/f9hj).

Animal behaviour

Blast of sound could avert bird collisions

PROJECTING white noise in the direction of oncoming birds could stop them from colliding with buildings or wind turbines.

Birds keep their heads down to streamline their bodies as they fly, says John Swaddle at the College of William & Mary in Virginia. That is why billions of them die each year in collisions with structures.

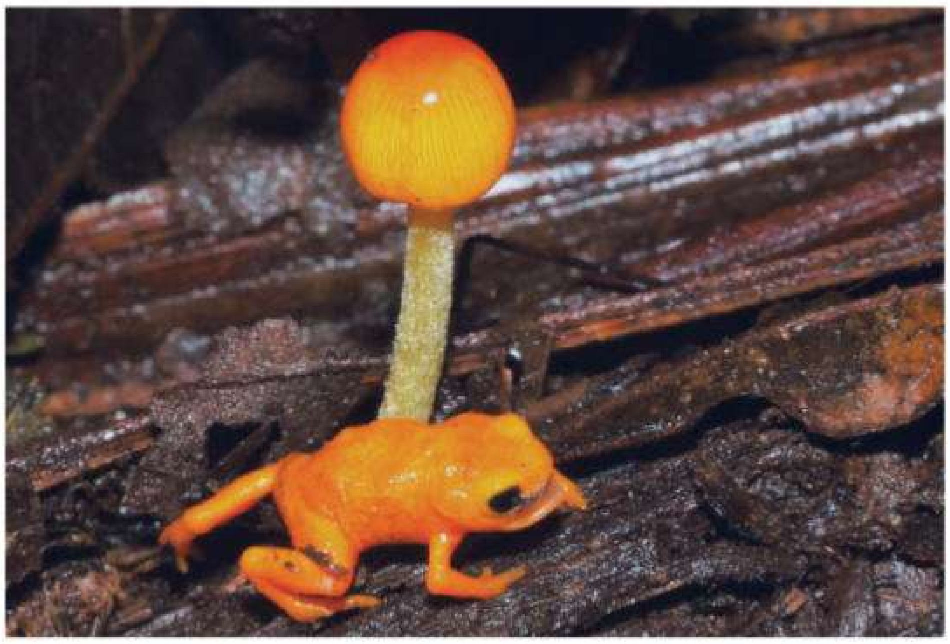
He and his team used white noise at around 70 decibels, about as loud as a vacuum cleaner, to try to get the attention of birds when they flew near tall structures. The team used directional speakers on two communication towers on the Delmarva peninsula in Virginia, an area that millions of birds pass through while migrating south during the autumn. The speakers were angled to only be heard by oncoming birds flying south.

The team broadcast two sounds at different times within the frequency range that most birds can hear, playing them for 30 minutes at a time followed by silence for 30 minutes. One sound fell between 4 and 6 kilohertz, the other between 6 and 8 kilohertz.

Compared with the periods of silence, bird activity fell by roughly 16 per cent around the towers when the 4-6 kilohertz sound was played, and by 12 per cent while the sound at 6-8 kilohertz played.

When birds flew to within 100 metres of the tower, they were considered at risk of a collision. But the lower frequencies caused them to slow down more and divert further around the tower (*PLoS One*, doi.org/f9g9). Swaddle says this may be because birds hear frequencies between 4 and 6 kilohertz better. **Ibrahim Sawal**

Biodiversity



EDELCIO MUSCAT

Welcome to the gang: tiny, toxic frog is a new species

PUMPKIN toadlets are poisonous frogs with brilliant orange skin that are small enough to fit on a thumbnail – and now a new species has joined their ranks.

Ivan Nunes at São Paulo State University in Brazil and his team suspected a local toadlet species (*Brachycephalus ephippium*) was more than one species.

They collected wild toadlets, measuring and comparing the physical features of 276 frogs. The team also conducted 76 field surveys between October 2018 and September 2019 to study toadlet behaviour and habitat use.

The researchers also included museum specimens from a range of 200 kilometres. They analysed DNA samples from 71 toadlets, and recorded the mating calls of several males to see how they compared with those of close relatives.

The researchers found that a type of toadlet (pictured) in Brazil's Mantiqueira mountains – a rugged, forested landscape with a diverse array of frogs that are found nowhere else – was distinct. It is smaller than *B. ephippium*, with faded black spots and DNA that differs by about 3 per cent. These facts warranted classification as a new species: *B. rotenbergae* (*PLoS One*, doi.org/f9fh). JB

Health technology

Skin patch can tell when you scratch

FEELING itchy? A body sensor can tell how bad it is by tracking how often you scratch yourself.

Itching is associated with many diseases, but diagnosing chronic itching is hard as there is no objective way to measure how it feels. To address this, Steve Xu at Northwestern University in Illinois and his team have created a soft, waterproof sensor worn on the dominant hand to do just that.

It measures the motion of scratching as well as picking up sound generated by nails on skin and uses a machine learning algorithm trained to determine when people are scratching.

The team tested the sensor on two males and nine females, aged four to 24, all with eczema, a condition that causes intense itching and leads to chronic sleep disturbance in about 60 per cent of affected children.

They compared the performance of the trained algorithm with recordings from infrared cameras, which captured the participants scratching at night while wearing the sensors. They found the assessments of itching matched 99 per cent of the time (*Science Advances*, DOI: 10.1126/sciadv.abf9405).
Krista Charles

Discrimination is still a problem in STEM

Harassment and discrimination based on gender, age and ethnicity continue to be major issues in the workplace that affect a significant proportion of STEM industry workers, according to the 2021 New Scientist Jobs/SRG survey. **Gege Li** reports

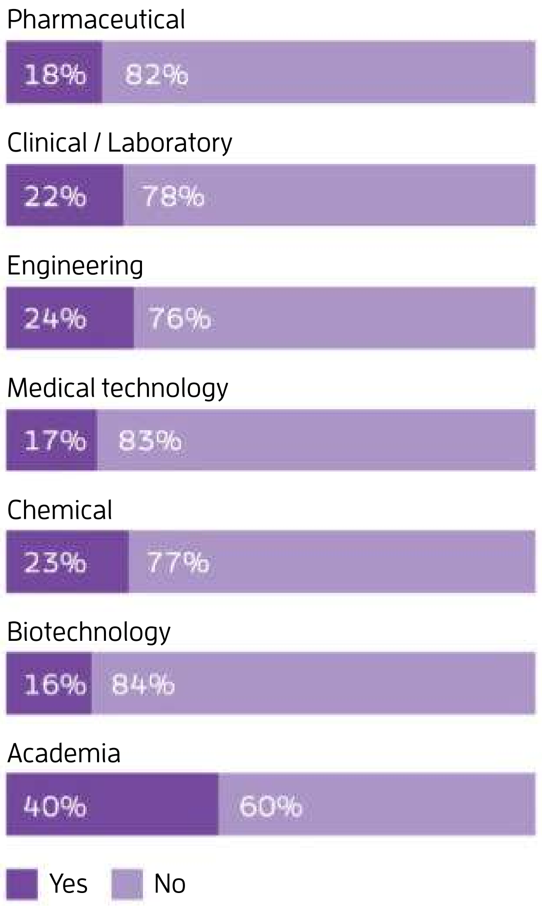
A HAPPY workplace is a productive workplace, or so the saying goes. But this year's New Scientist Jobs STEM Industry Survey in association with science recruiter specialist SRG reveals that, in terms of discrimination and harassment, there is still a long way to go in guaranteeing employee happiness and security. The survey raises several key themes of concern to the STEM workforce, and suggests how employers can best tackle these problems to make workplaces as inclusive as possible.

Almost 2400 people working in a range of STEM industry sectors from the UK, the rest of Europe and North America took part in this year's survey. In the UK, almost a quarter said they had experienced discrimination or harassment of some description in their line of work, a similar proportion to the previous year. In Europe and the US, the figure increased to 30 per cent. Workers from all STEM industry sectors were affected, although reports of discrimination and harassment were highest in academia at 40 per cent. The lowest number, 16 per cent, was in the biotechnology sector.

Women reported more discrimination than men in all regions. That is concerning, especially in Europe and the US, where more men answered the survey – 61 per cent of respondents in Europe were men and 38 per cent were women, while in the US it was 59 per cent versus 38 per cent respectively. The weighting was more balanced in the UK, with a split of 47 per cent men and 52 per cent women.

Of the possible grounds for discrimination, 43 per cent of overall respondents said they had been targeted based on their gender, with gender inequality already being a well-established problem in STEM. For women, this frequently entailed experiences of sexism and misogyny, particularly by their male colleagues, as well as biases about their ability to work effectively if they were pregnant or had children or not.

Discrimination by sector (UK)



UK respondents

SOURCE: NEW SCIENTIST/SRG/2021 SALARY SURVEY

> "The survey makes clear that discrimination is still a very real and current problem in STEM industries"

Of those who were willing to elaborate on their experiences, one female respondent said: "I face sexist comments frequently and also inappropriate comments about how I look or my body." Another said they were "constantly fighting and losing against the 'old boys club'."

Career opportunities also seemed to be lacking for some women. For example, one commented: "I feel I have been offered less progression after three years than my peer, who just started and is male, after 6 months. He is included in wider company emails, events and meetings that I am not – even though it is integral to my role to be so."

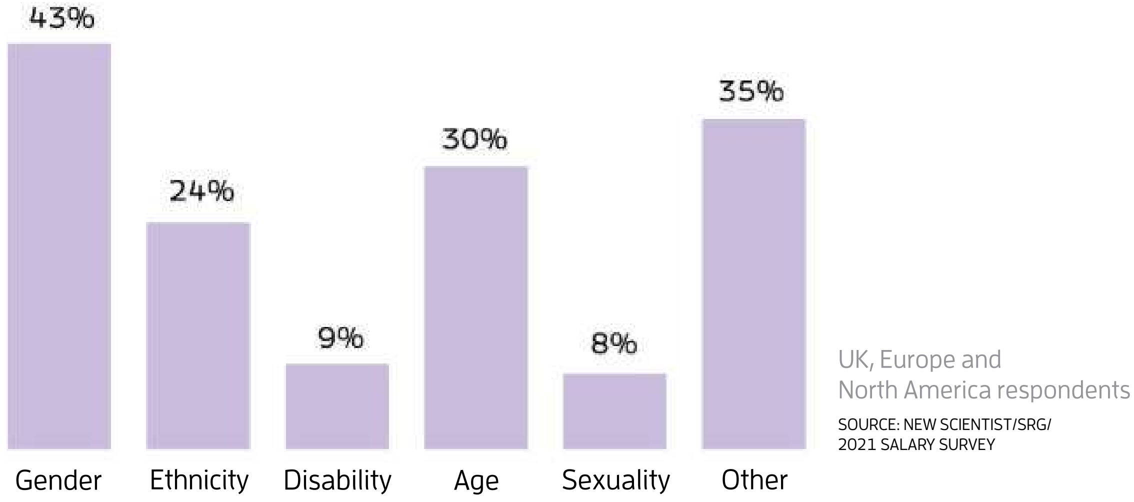
The gender pay gap remains an issue, too, despite increased efforts to narrow the divide. In the UK, the survey puts it at around 19 per cent – men in STEM earned roughly £3500 more than the UK average STEM salary of £43,424, while women earned £4000 less than it.

Meanwhile, some men felt their company's obligation to achieve a more gender-balanced workforce came at the detriment of their own progression. "I am not a woman and therefore regularly lose out to female candidates that are less qualified but enable employers to reach their legal gender quota," said one.

Another common basis for discrimination in our survey was age, comprising 30 per cent of respondent experiences. One person aged between 20 and 24 said: "Although not intense, as I am much, much younger than most of my co-workers, it is quite evident that the way I used to be spoken to especially was very dumbed down."

For the first time, our survey gave those answering in the UK the option to state their ethnicity. Most respondents were white at 80 per cent, while 11 per cent were Asian, 3 per cent were Black, 4 per cent were of a mixed or

Basis of discrimination



UK, Europe and North America respondents

SOURCE: NEW SCIENTIST/SRG/ 2021 SALARY SURVEY

SOLSTOCK/ISTOCK PHOTO

multiple ethnicity and 2 per cent were of any other ethnic group, a composition that is generally on par with the wider UK population.

Twenty-four per cent of respondents reported experiencing ethnicity-related discrimination, with one in the UK saying: "They see the colour of my skin before my skills [and] abilities in carrying out the tasks... I [have] been treated as an outsider sometimes. They make you feel you are less intelligent and I think this is not right." Exclusion and unfair or different treatment were routine issues among these respondents, some of whom said they had been completely ostracised from the rest of their team or company on the basis of being from a different country.

People also faced prejudices based on disability or sexuality, making up 9 per cent and 8 per cent of respondents respectively. Some 35 per cent cited discrimination or harassment for a reason not listed. Certain experiences were multifaceted – for example, relating to both gender and age.

Despite these reports, around 70 per cent of respondents said they were content in their jobs overall. Since people were free to report on any experiences throughout their career, it is safe to assume that at least some of these occurred outside of their current roles.

It might also suggest that people either don't consider discrimination and harassment to particularly infringe on their jobs, or that they didn't factor these aspects in so much to their overall satisfaction. Given the sometimes serious incidents raised by several respondents, the latter could be a more likely explanation. Perhaps the feeling that their issues weren't or wouldn't be taken seriously or properly dealt with by management, as some respondents divulged, played a part in their judgement of this factor.

The survey makes clear that discrimination is still a very real and current problem within STEM industries. The high proportion of our respondents citing some sort of bias towards them implies current measures are insufficient on the whole. Thoroughly addressing these gaps to ensure that people feel secure and attended to in their workplace should be a key consideration for employers and companies. That means not only appropriately dealing with incidents when they are raised, but ensuring that sufficient policies are in place to protect workers from mistreatment and bullying in the first place.

Gege Li is a freelance writer based in London. Download the full salary survey at newscientist.com/stemreport

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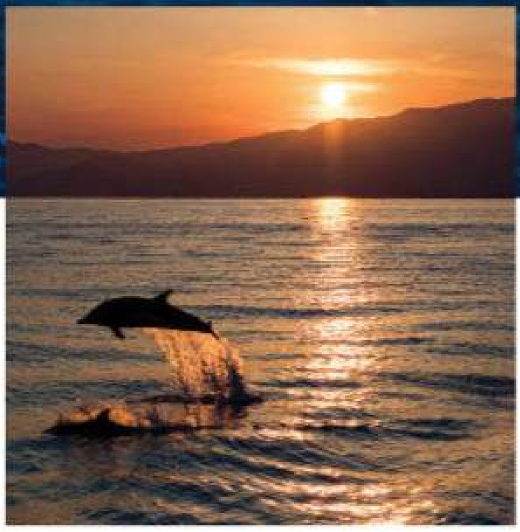
8 days | 21 May 2022

Portugal: Marine ecosystems of the Azores



The Azores are a paradise. Lush vegetation, volcanic craters, lagoons, and picturesque towns are nestled in the rich biodiverse waters of the North Atlantic. Accompanied by a team of marine experts and marine biologist Jon Copley, you will spend time both at sea and on land surrounded by a host of different species. Spot the blue whale, the world's largest mammal, and the sperm whale, boasting the world's largest brain. Among others you may also see species such as baleen, pilot, and fin whales, bottlenose, risso, spotted and striped dolphins.

You will spend your days exploring the land and sea, learning about marine life, intelligence and ecosystems through a series of talks, as well as actively take part in whale research, the data of which is used around the world.

Highlights

- Two full days at sea with researchers from the University of Lisbon and Azores to spot whales, dolphins, turtles, and birds.
- A hands-on experience as you learn about global conservation efforts and how data is shared as you help collect and measure microplastics in the ocean as well as acoustic records of the different whales and dolphins in the nearby waters.
- Evening talks and floating seminars at sea from marine biologist and ocean explorer Jon Copley, covering behavioural ecology of sea mammals, the hydrothermal vents off the coast of the Azores and many other subjects.
- Discover the town of Sete Cidares, nestled in a 3-mile-wide volcano which is also home to both blue and green crater lakes.
- Explore many of the fascinating areas of the Sao Miguel Island, including a stop at a tea plantation and various beautiful viewpoints
- Ferry ride to Pico Island where you will enjoy a visit to a local vineyard in a UNESCO Protected Landscape, views of lagoons and volcanic cones, and a trip to the Whaler's Museum.
- Accompanied by a biologist, you will visit a local nature reserve, where you can expect to see an exceptionally large Cory's Shearwater seabird colony. With the breeding season at its peak in May, this will be an unforgettable experience.
- Explore Faial including central Caldeira and the unique lunar landscape of the Capelinhos volcano. From volcanoes to endemic forests, breath-taking lookouts, and landscapes, enjoy a series of short walks amidst the nature and culture of the Azores.

Covid-19 safety protocol includes:

- Pre-departure screening of all guests and tour leaders.
- Increased sanitisation of all accommodation and transport.
- Mandatory use of PPE where appropriate.

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Views

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Comment

Life under ice

I lived under a glacier studying methane-producing microbes. We still have much to learn about their climate impact, says **Jemma Wadham**

MICHELLE D'URBANO

CHISELLED, grey rock walls loom on all sides, brought to life by the faint beam of my headlamp. Tiny rivulets of groundwater form a tangle of silver threads around me. As I inhale, I smell the heavy scent of cold, damp, stale air, which clings to my face like an invisible cloth. Slowly, I drag my welly-clad feet along the seemingly endless dirt track towards the eye of the tunnel ahead and the guts of the glacier.

I have never had much of a proclivity for caves, but here I was living in a labyrinth of tunnels beneath the Norwegian glacier Engabreen of the Svartisen ice cap. I spent two weeks here in the winter of 2006, coming to visit its tantalisingly named "subglacial laboratory", where you could access the glacier bed thanks to tunnels originally bored through the mountain to tap the copious meltwater for hydroelectric power.

The laboratory was equipped with an ingenious means of getting to the inhospitable glacier bed. You would open up a shaft (with a door made of iron girders) to reveal the dirty, basal layer of the glacier topped by a translucent, 200-metre-thick mass of slowly moving ice and then melt your way in with a hot-water drill. My reason for being there was a grand hunt for microbial life and one of its troublesome by-products, methane.

Methane is a potent greenhouse gas: it has around 80 times the warming power of carbon dioxide over 20 years. Some of the places most notorious for its production are rice paddies, landfill sites, wetlands and even the stomachs of cows, but, increasingly, it seems like glaciers could be hotspots too.

That is because one type of microbe that thrives in the oxygen-starved conditions beneath a glacier is a methanogen, or "methane maker". Its carbon supply comes from ancient soils, lake sediments and marine muds that were entombed by the glacier when it grew. Remarkably, some methanogens may be fed by hydrogen produced as the glacier grinds over its rocky base.

If it were possible to venture deep into the vast basins of sediment buried beneath ice sheets in geothermically active zones, we think you would find methane forming without the input of life through the slow heating of carbon in these sediments.

My toils beneath Engabreen enabled me to obtain mud from the glacier's bed, which I added to our burgeoning collection sampled by chainsaw from the edges of other glaciers around the world. We recreated the glacier bed in the lab using simple experiments with glacial mud and meltwater. Two years later, measurable biological methane had been produced in all glacier samples, save those from Engabreen. Here, there was just hard rock and not enough carbon for microbes.

Since then, the evidence for glaciers as methane producers has exploded. In 2015, we found that rivers issuing from the margin of the Greenland ice sheet were supersaturated with the gas. High concentrations have also been found in other glacier rivers, a subglacial lake in West Antarctica and even the dirty layers of ice cores. In deep parts of ice sheets, we worry that methane might be stored in its solid form, methane hydrate. As climate change thins ice sheets, this could be released as gas.

Research by Norway's Centre for Arctic Gas Hydrate, Environment and Climate indicates that this happened to methane beneath former European ice sheets around 10,000 years ago as they collapsed after the last glaciation. Might this occur to current ice sheets in a warming world?

The jury is still out on whether glacier methane is a whiff of something small or something world-changing for our climate, but, regardless, we need to find out if we are going to halt global warming. ▮

Jemma Wadham is at the University of Bristol, UK. She is the author of *Ice Rivers*, which is out now

No planet B

Crimes against nature There have long been calls for international laws to recognise ecocide as a crime. Now that movement may finally have a chance, writes **Graham Lawton**

Graham Lawton is a staff writer at *New Scientist* and author of *This Book Could Save Your Life*. You can follow him @grahamlawton

THOSE of us who write about the state of the environment are accustomed to being the bearers of bad news, and it is easy to become numbed by the scale of the destruction. But some stories retain the power to shock. One of them hit me hard a few weeks ago.

A widely reported research paper set out to discover how much of Earth's land is ecologically intact, meaning that its ecosystem remains in a pristine, pre-industrial state. The answer: just 3 per cent. To frame it differently, in the past 500 years, humans have degraded 97 per cent of the terrestrial biosphere.

There is, I think, only one word for such levels of destruction: ecocide. Like genocide, it isn't a word to be thrown around casually. But what else does justice to that degree of destruction?

Speaking of justice, that is exactly what some activists would like ecocide to lead to. Their long-standing goal is to have ecocide recognised in international law alongside crimes like genocide.

Those who bring destruction on nature could find themselves at the International Criminal Court (ICC) next to the perpetrators of the most heinous crimes against humanity. This idea has long been on the fringes of environmental activism, but it now has a genuine chance of being written into the statute books.

Like laws for crimes against peace, an ecocide law would trace its roots to wartime atrocities, in this case the annihilation of forests in South-East Asia, first by the UK's Royal Air Force during the guerrilla war known as the Malayan Emergency and later by the US Air Force in the Vietnam war. In 1970, the destruction inspired Arthur Galston, a plant biologist at Yale University whose PhD research had led to the development of agent orange, to coin the word "ecocide".

Calls to make ecocide a crime followed these events, though with limited success. The 2002 treaty that created the ICC originally included an ecocide law, but it was scaled back after objections from the UK and US (wilful environmental destruction in wartime is a crime, but nobody has been prosecuted for it).

But campaigners stuck to the task and criminalisation has slowly gathered support. Last year saw a significant breakthrough when two of the ICC's member states, Vanuatu and the Maldives, asked the court to "seriously consider" criminalising ecocide. President Emmanuel Macron of France has backed their request and the government of Belgium has also indicated support.

> **"A law against ecocide would be a powerful deterrent against environmental destruction. Or would it?"**

An expert legal team convened by the Stop Ecocide Foundation is now drafting what it hopes will be a workable legal definition of ecocide. It aims to publish next month, at which point one or more member states of the ICC could formally propose making ecocide a crime. That would set the ball rolling towards ratification.

The road is long and so are the odds, but I hope the endeavour succeeds. A law against ecocide would be a powerful deterrent against environmental destruction. Or would it? Not everyone in the green camp is sure.

Last month, I hosted a *New Scientist* event called A Rescue Plan for Nature. We invited a distinguished panel to answer questions submitted by the audience. One was on whether ecocide should be a crime.

I expected a resounding yes, but didn't get one. Partha Dasgupta, an economist at the University of Cambridge, said: "It's something we could aspire to in the future but it's far too early." Even though there is a strong philosophical argument in favour, he said, the practical danger is that we get bogged down in legal definitions and end up achieving nothing.

I have great respect for Dasgupta and his answer gives me pause. Making ecocide a crime has enormous instinctive appeal. But as a real-world measure, would it do anything? Pursuing alleged war criminals though the ICC has proved time-consuming and difficult enough. When it comes to ecocide, who would be in the dock?

On reflection, I am still in favour. Such a law would not only seek retribution and deterrence but also draw moral red lines. Yes, securing convictions for crimes against peace has proven difficult, but nobody can be left in any doubt that those crimes are totally beyond the pale. The biosphere deserves the same moral status.

I will leave the last word to Polly Higgins, a barrister who gave up a career in corporate law to become one of the most effective backers for criminalising ecocide. As she wrote in 2013, "For now, in law outside of wartime, it is not a crime to cause mass destruction or loss of ecosystems. Our world has normalized... ecocide".

Higgins died in 2019 with her mission unaccomplished, but the dream didn't die with her. We need a new norm, and establishing that ecocide is among the most serious crimes there is would be a just way of achieving it. ▮

Graham's week

What I'm reading

The Fifth Crime, *a series of in-depth reports from non-profit news outlet Inside Climate News and NBC News about the ecocide campaign.*

What I'm watching

Line of Duty *and a cold-case drama called* Unforgotten, *which somehow passed me by.*

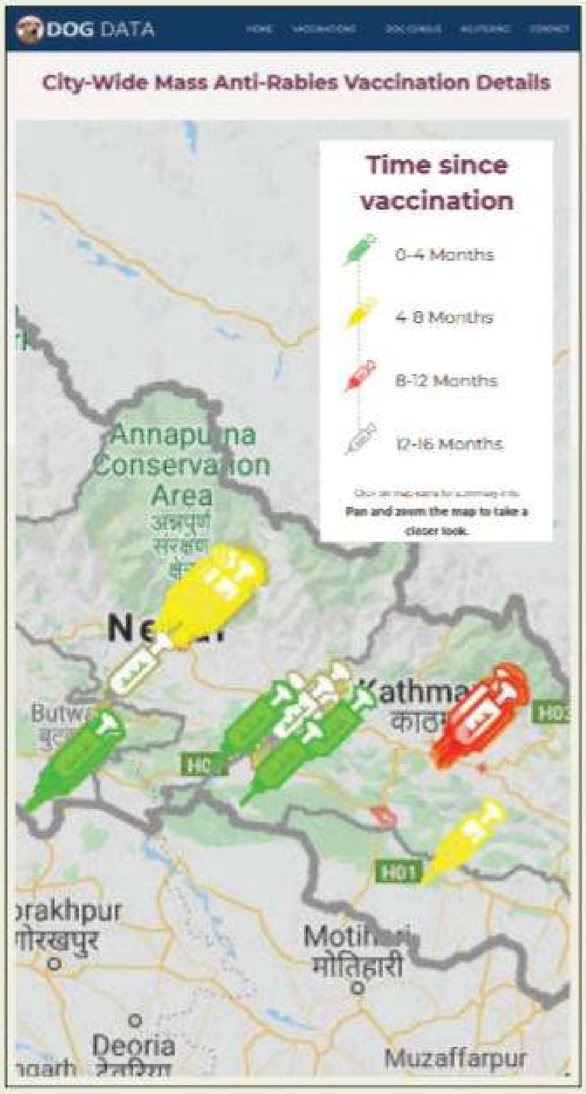
What I'm working on

Remembering how to go to the pub.

This column appears monthly. Up next week: Annalee Newitz

Welcome to our Signal Boost project – a page for charitable organisations to get their message out to a global audience, free of charge. Today, a message from **Himalayan Animal Rescue Trust**

HART
Himalayan Animal Rescue Trust



Pan and zoom the map to take a closer look.

Using technology to improve life for animals

The Himalayan Animals Rescue Trust, or HART, works with street dogs in Nepal with the aim of making their harsh existence easier to bear. Neutering, vaccination, rescue and treatment programmes are carried out at bases in Pokhara and in Chitwan, and in outreach programmes throughout the country. Animals that are healthy and safe receive care and protection in their communities.

In order to record anti-rabies vaccination activity, several years ago HART created an app that logs the details and location of each injection delivered. Subsequently the DogData website was established (www.dogdata.uk). Data from the apps is uploaded to appear on the site's maps, which can then be used by any stakeholders who are interested in understanding the protection level of their immediate community.

The app has been made available to other NGOs working in Nepal and thus a nationwide picture of vaccination coverage (or lack of coverage) is emerging. Since vaccination coverage does not last much more than a year the injection symbols fade away and disappear after 16 months.

In addition to vaccination details the site shows census counts of street dogs and details of neutering work. HART staff have recently completed a vet trek along the Everest Base camp trail in collaboration with the Khumbu Pasang Municipality and their work can be followed day by day on the DogData website. This may be of passing interest to anyone who has trekked the route, but the information is of vital importance to the people in the villages who can see exactly when their animals were vaccinated and neutered.

Although technology cannot replace vet care, food and medicine it can assist in providing these in a measured and sensible fashion. We are looking for help in promoting the DogData concept in Nepal. For further information on this aspect of our work, or to add your Nepal data, please contact Jim Pearson at j.pearson@dogdata.uk or Khageshwaar Sharma at k.sharma@hartnepal.org.

Want to help?

See above for how to assist the DogData project in Nepal. Or if you want to help the dogs directly, and learn more about our work in action, please visit **www.hartnepal.org**

Editor's pick

State deals on climate will need support of the people

Leader, 24 April

From Richard Rouse,
Reading, Berkshire, UK

The UN climate summit, COP26, may be a historic chance to secure the future, but a question looms even if new agreements are struck at the state level: will individual behaviour change?

Even before lockdowns end, millions are booking flights. For just one G7 meeting in June in the UK, the local airport is being upgraded. Are the super-rich giving up their luxury lifestyles for a flat and one holiday a year? Will heads of state lead the way, exchanging their palaces for a small house?

Replacing fossil fuels with batteries is a solution. But with ocean mining for the necessary mineral resources likely, David Attenborough's next TV series will be *Mucky Brown Planet III*.

Maybe attendees to COP26 should party like it's 1999, as it doesn't look to me like there will be a 2099 worth celebrating.

Transition to green living is looking very tricky

24 April, p 34

From John Neimer,
Stoborough, Dorset, UK

Many people will be deterred from thinking that they can do anything to help reduce greenhouse gases because many proposals seem impractical.

For example, the idea that many millions of people can switch to electric vehicles may fall foul of circumstances that arise a fair bit. For instance, imagine terraced houses with no front gardens and narrow pavements. Where are the charging points going to go?

Similarly, not everyone will be able to switch from gas-fired boilers to heat pumps as many homes have no land for a ground heat pump system and air pumps will struggle to provide sufficient reliable heat and hot water for an average family. We must keep the likes of waste-to-heat-and-power generators or small nuclear reactors on the table.

And while we should reduce our intake of animal products, do it by not importing from countries such as Brazil where the forests are being destroyed. Similarly, outlaw palm oil in food and work to restore South-East Asian forests.

From Laurie van Someren,
Cambridge, UK

We need a better tool to allow us to calculate our carbon footprint to help us change lifestyles. The unit of this carbon footprint should be the Thunberg, after Greta.

Get fit without even leaving your armchair

24 April, p 46

From Jon Arch, Welwyn Garden City, Hertfordshire, UK

As you report, there is a long history of attempts to design drugs that mimic the effects of exercise. But why use drugs?

I was at a conference about 15 years ago where a presenter claimed he had been able to train for a marathon while sitting at home watching television, with his legs jerking (quite violently in his video) in response to electrical stimulation. Commercially available machines that do this don't seem to work quite as well (or violently).

A virtual answer to the dark matter mystery?

17 April, p 14

From Bryn Glover, Kirkby Malzeard, North Yorkshire, UK

Your story "Muons point to new physics" brought to mind an issue that has nagged me for a while.

If pairs of particles/antiparticles "pop into existence" and then vanish "moments" later, they would, nonetheless, be part of our physical universe for very short periods of time. They also have mass, which is (presumably) the same for both partners in the pair.

I am curious as to whether proposals for dark matter to account for the missing mass that astronomers say is needed to explain the universe take into account the aggregate masses of all the possible virtual particles.

Icy era could have led to retreat into woodlands

24 April, p 16

From Dudley Miles, London, UK

Erle Ellis and his colleagues argue that as far back as 12,000 years ago, 95 per cent of temperate woodland was shaped by human societies.

Earth was then in the grip of the Younger Dryas, a glacial period that caused large areas of the northern hemisphere to be covered with ice and tundra, so the area of woodland would have been much lower.

There might have been a reduction in untouched woodland at this time because people living in northern regions were forced south, increasing the population density in the surviving temperate forests.

We may have to revise the view on Planet Nine

3 April, p 34

From Sam Edge,
Ringwood, Hampshire, UK

The idea that a tiny black hole may lurk in the far reaches of our solar system, rather than a ninth planet, is based on its position, which doesn't fit with current theories of planetary evolution.

This reminds me that, until very recently, our theories also precluded gas giants close to their stars. The discovery of many "hot Jupiter" exoplanets resulted in some hasty revisions to that idea.

Spiders seem to love a bit of Beethoven

17 April, p 12

From Colin Heath,
Cardiff, UK

Ian Morse's story on spiders and interpreting their web vibrations as music leads me to conclude that tunes played near webs cause spider activity.

I have three social distancing spiders in my conservatory. When I play Radio 3, they shoot out and run about, especially to percussive or piano pieces. It must be vibrating certain web strands. When they find no struggling insects, they retreat.

Forget town twinning, try toilet twinning instead

17 April, p 21

From John Hastings,
Whittlesey, Cambridgeshire, UK

Priti Parikh is right to draw attention to the importance of good sanitation and clean water supply in tackling childhood undernutrition. While governments should be addressing this, it is possible for anyone to make a contribution.

The charity Tearfund has a system of "toilet twinning". For a donation, you can twin your own toilet with one the charity will fund in a low-income country. Mine is twinned with one in Sierra Leone. There are nearly 30 million households in the UK. If every one of them twinned a toilet, it would make a significant dent in the problem that Parikh highlights.

For the record

- **Our story on Iceland's Fagradalsfjall volcano (24 April, p 28) meant to refer to the Reykjanes peninsula.**
- **Francis Crick coined the term central dogma, which describes the flow of genetic information (3 April, p 52).**

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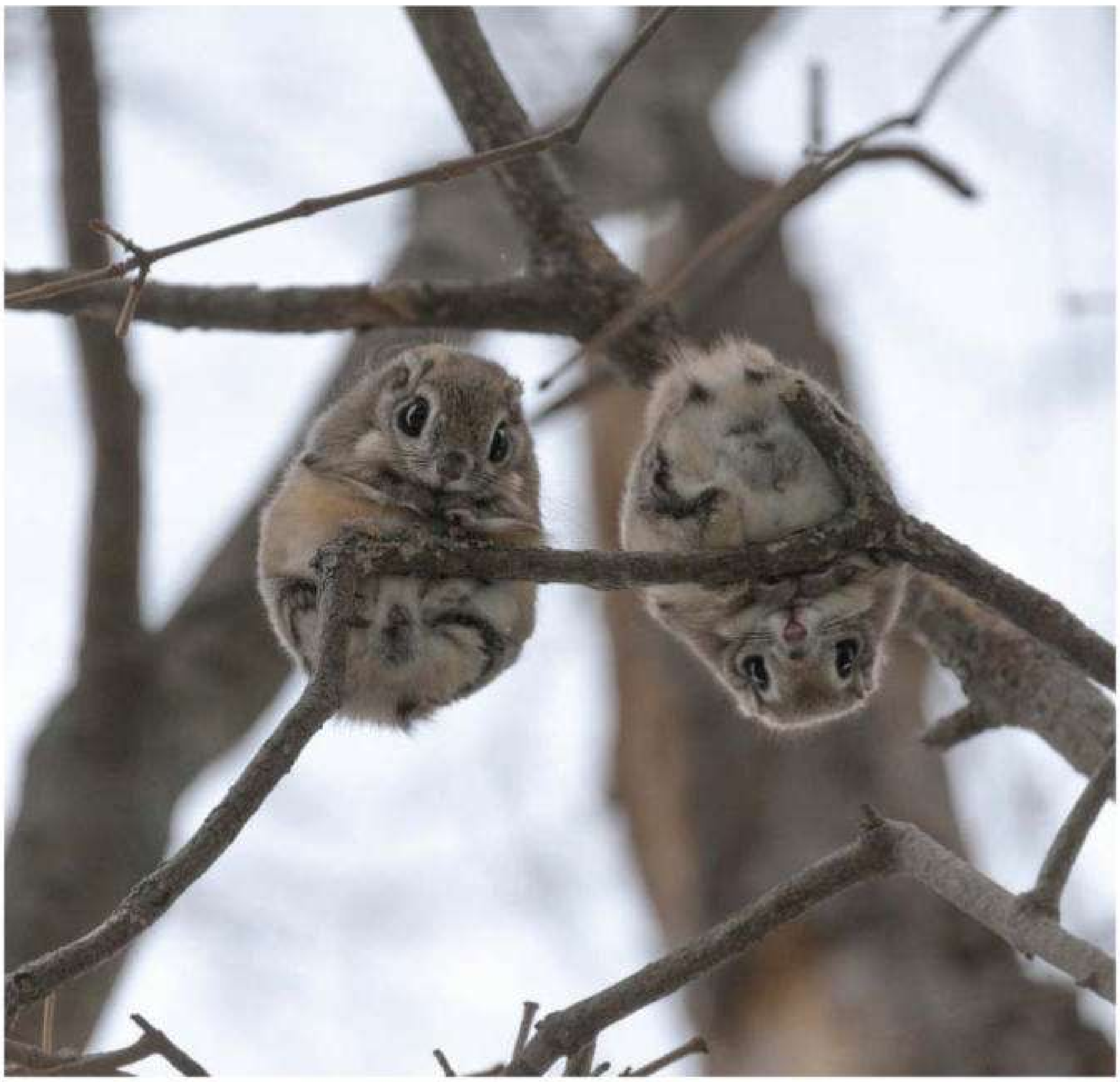

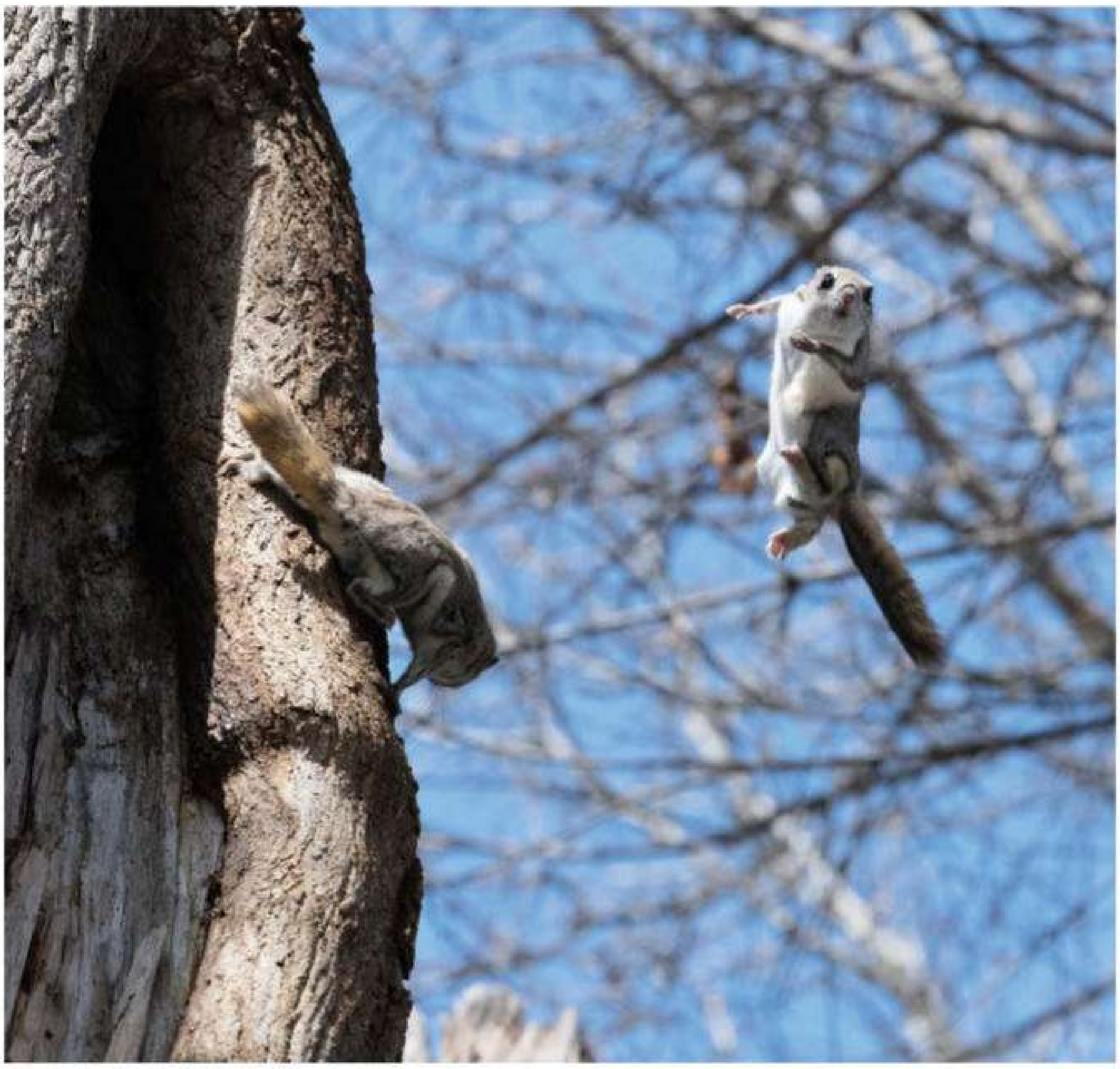

Flying feats

Photographer **Tony Wu**
Agency **NaturePL.com**

THE large image (far left) shows one of Japan's most charismatic and rarely seen residents as it glides through its Hokkaido habitat: *Pteromys volans orii,* a subspecies of the Siberian flying squirrel.

It and the other squirrels on these pages were captured by photographer Tony Wu, who spent several weeks in their snowy home during mating season. Siberian flying squirrels are hard to spot, and this opportunity was mostly down to luck, says Wu, since the animals are nocturnal and are usually high off the ground.

Like all flying squirrels, they don't actually fly, but use the skin membranes between their forelimbs and hindlimbs, called patagia, to glide from tree to tree. They can soar for some 50 metres – an impressive feat for an animal that only grows to be up to 23 centimetres long.

Hokkaido is the northernmost prefecture of Japan and the only place in the country where this subspecies of Siberian flying squirrel is found. Further south, on the Honshu and Kyushu islands, they have been replaced by the Japanese dwarf flying squirrel (*Pteromys momonga*).

Next to the gliding squirrel, a pair of squirrels (near left, top) peek out from the branches after foraging for food. Below, two males fight for the right to mate with a female. The image captures the moment when one male body-slammed the other off the tree, although Wu says the squirrel was able to glide to a safe landing. ▮

Gege Li

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Dan Hooper is a senior scientist and the head of the theoretical astrophysics group at the Fermi National Accelerator Laboratory, as well as a professor of astronomy and astrophysics at the University of Chicago. His research focuses on the interface between particle physics and cosmology, and he is especially interested in questions about dark matter and the early universe.

Chris Impey is a University Distinguished Professor of Astronomy and Associate Dean of the College of Science at the University of Arizona. He has over 180 refereed publications on observational cosmology, galaxies, and quasars, and his research has been supported by $20 million in NASA and NSF grants.

Fiona Panther is a research associate at The University of Western Australia in Perth. She is a physicist and mathematician with an interest in astronomy and software development. Her expertise is primarily in microphysical astronomy: how processes that occur on the atomic and subatomic scale can influence what we observe on galactic and cosmological scales.

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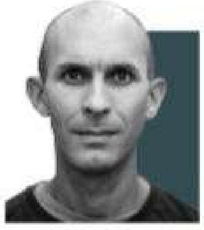
MEET YOUR EXPERT COURSE TUTORS:

Penny Lewis is a sleep scientist and professor of psychology at Cardiff University. She has coined the term sleep engineering to capture the spirit of her lab's work. She explores ingenious ways to enhance memory, disarm negative emotions, and combat cognitive decline through ageing during sleep. Her book, *The Secret World of Sleep* explores the latest research into the night time brain to understand the real benefits of sleep.

Sophie Scott is professor of cognitive neuroscience at University College London. As head of the speech communication group, her research focuses on how our brains process the information in speech and voices, and how our brains control the production of our voice. Her work also explores individual differences in speech perception and plasticity in speech perception, both of which are important factors for people with cochlear implants.



Anil Seth is professor of cognitive and computational neuroscience at the University of Sussex. His research seeks to understand the biological basis of consciousness by bringing together research across neuroscience, mathematics, computer science, psychology, philosophy and psychiatry.

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Making electronic waves

A group of pioneers made many electronic music breakthroughs but their work hasn't always got the recognition it deserves, finds **Bethan Ackerley**

Film

Sisters with Transistors

Lisa Rovner

Select cinemas; virtual release on BFI player, Metrograph

"HOW do you exorcise the canon of classical music of misogyny?" asks narrator Laurie Anderson in *Sisters with Transistors*. "With two oscillators, a turntable and tape delay." Directed by Lisa Rovner, the film celebrates the women whose breakthroughs in early electronic music laid the foundations of modern styles – and whose work has been overlooked by many.

It starts by showing how the events of the 20th century shaped women and electronic music alike. After a brief sequence in the 1930s with Clara Rockmore, a virtuoso theremin performer, it moves to the second world war. Musician Delia Derbyshire cited the air raid sirens during the bombing of Coventry, UK, in 1940 as the beginning of her obsession with abstract noises. From the carnage of the old world, a new, electrified sound was born, one that women would be key to defining.

Musicians like Éliane Radigue and Pauline Oliveros were inspired by machines, from droning planes to the crackling static of short-wave radios. The tech underpinning the music was varied too. Some artists used tape recorders or modulators to create wondrous sounds; Bebe Barron and her husband Louis overloaded circuitry. In a glowing endorsement, writer Anaïs Nin said their work sounded like "an electron that has stubbed its toes".

This new form of music found an appreciative audience through film and television, often thanks to the work of women behind the scenes. Composer Daphne Oram was instrumental in creating the BBC Radiophonic Workshop, an experimental sound effects unit that introduced new musical technologies to the masses.

"Without Daphne, it would never have started," says alumnus Brian Hodgson, creator of the sound of the TARDIS in *Doctor Who*. The show's theme was made at the workshop by Derbyshire, who, in a time before samplers and synthesisers, spent 40 days splicing sounds by hand to bring Ron Grainer's composition to life.

> **"The debate over what constitutes legitimate music was a large part of what drew women to electronic sound"**

Yet there were many obstacles on electronic music's path to mainstream success. Take the Barrons' soundtrack for sci-fi classic *Forbidden Planet*. It was the first entirely electronic score for a film, but it upset the Musicians' Union, reportedly due to fears of machines taking performers' jobs. The Barrons' work was ultimately billed as "electronic tonalities", rather than music.

Sisters with Transistors argues that the debate over what constitutes legitimate music – and who gets to perform it – was a large part of what drew women to electronic sound. "You didn't have to be accepted by any of the male-dominated resources," says composer Laurie Spiegel.

Despite how integral the film's subjects were to the development of electronic music, their artistry is often sidelined in mainstream musical histories. The way the film throws light on this injustice is made all the more fascinating by how it is balanced with time spent appreciating the artists' music. Long, ethereal sequences are devoted simply to listening, with scenes tied loosely together by Anderson's magnetic narration.

The downside of this approach is that there is so much more that could be said. No single film could feature it all, of course, and *Sisters With Transistors* doesn't try to be all encompassing. Yet some fascinating details are absent: Derbyshire's time in experimental band White Noise and Wendy Carlos's soundtrack for the film *Tron*, for instance, were huge influences on many artists.

Experimental electronic music might not be everyone's cup of tea. That said, I defy you to watch *Sisters With Transistors* without feeling transported to another time and place. Let the stories of these women and their work wash over you, and you will find yourself caught in the current. ▮

PEGGY WELLS

Composer Maryanne Amacher's tape recorders were central to her music

When worlds collide

A documentary tells the remarkable story of a chimp that lived like a human and a human that lived like a chimp, finds **Elle Hunt**

Film

Lucy, the Human Chimp

Directed by Alex Parkinson

All 4 in the UK and HBO Max in the US

HBO MAX

Lucy, the Human Chimp explores the relationship between the two species

SO MUCH is now known about our similarities to other primates, it is easy to forget that, until relatively recently, we were still establishing where humans ended and apes began. In the 20th century, the study of chimpanzees in particular was a way to learn about ourselves: how we might fare in space, for example, or communicate in the absence of a common tongue.

Lucy, the Human Chimp, a new TV documentary, explores the meeting of those worlds through a unique relationship: the one between Lucy, a chimpanzee raised as a human, and Janis Carter, a graduate student hired to clean her cage. In the late 1960s, Lucy was the subject of a high-profile study by psychologists Maurice and Jane Temerlin, ostensibly to explore the limits of nature versus nurture.

The Temerlins brought Lucy up in their home more or less as though she was a human child, to the point of teaching her to dress herself, eat with silverware and even fix a gin and tonic. Primatologist Roger Fouts, whose success teaching a chimp named Washoe a form of American Sign Language was heavily publicised in 1970, likewise taught Lucy a vocabulary of around 100 signs (though the extent of apes' comprehension of signing remains disputed). Eventually, the Temerlins came to regard Lucy as their daughter.

Much has been made of this, so director Alex Parkinson puts forward Carter to share what happened next. She became a part-time carer for Lucy in 1976. After a frosty start – the chimp was "arrogant, and very condescending" about her poor comprehension of sign language, she says – the two forged a close bond. But the adolescent chimp increasingly posed a threat to her human family, and was confined to a cage.

In 1977, the Temerlins decided to take 12-year-old Lucy to Gambia to be taught how to live in the wild; Carter went along to help. For her, a trip of a few weeks turned into years as Lucy struggled to adjust to life as a chimp. Carter lived for nearly seven years on an otherwise uninhabited island in the Gambia river, alongside Lucy and a small troupe of orphaned and captive chimps. Carter only left after a young male attacked her in 1985, supplanting her as leader.

> "For nearly seven years, Janis Carter lived with Lucy and other chimps on an otherwise uninhabited island"

The film's focus is on Carter and her relationship with Lucy, as told by Carter herself. An interview with Jane Temerlin and re-enactments by actors provide some context, but little by way of critical distance.

Carter's decades-long dedication to protecting Lucy – and now her species, as director of the Chimpanzee Rehabilitation Project in Gambia – is remarkable. But the film doesn't interrogate a view that Lucy, having been born and raised in captivity, was never a suitable candidate for rehabilitation into the wild, and suffered in the attempt.

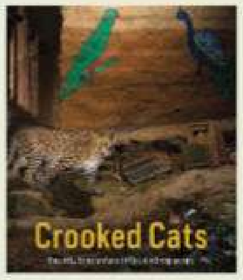
Apes invariably come off worse in their interactions with humans, even those that had the best of intentions. Lucy's life began in 1964, in a roadside zoo in Florida. It ended in mysterious circumstances a few years after Carter's departure; she was probably killed by a poacher.

Lucy, the Human Chimp is less concerned by the ethical questions provoked by Lucy's somewhat sorry existence. Instead, it is a fascinating study of the lengths and limits of chimps and humans' ventures into each others' worlds. Just as Lucy was raised a human, Carter lived as a chimp. But she ultimately had to extract herself and return to her own kind. "I couldn't live in both worlds," she says. ▮

Don't miss

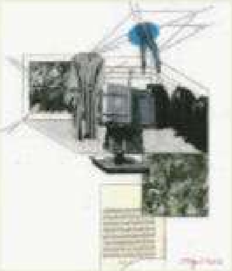
Watch

Oxygen, Alexandre Aja's sci-fi thriller, is the story of a woman with amnesia (Mélanie Laurent) who is trapped in a cryogenic chamber. Her oxygen is running out and she will survive only if she remembers who she is. On Netflix from 12 May.



Read

Crooked Cats tell their own bloody tales in anthropologist Nayanika Mathur's study of how big cats – tigers, leopards and lions – come to prey on humans. Ecological collapse is an important reason why such attacks occur, but is it the whole story?



Last chance

Cosmos: Reverse perspective looks at Earth from space through collages and graphics, capturing the changes we have lived through since Yuri Gagarin's first orbit. Online from Pushkin House until 18 May.

T:SHANNA BESSON/NETFLIX; B:PUSHKIN HOUSE

The games column

Finding a new you In *Disco Elysium*, you play a detective solving a murder, but the game is more concerned with taking the opportunities to reinvent yourself – and not worrying if you fail, says **Jacob Aron**

Jacob Aron is *New Scientist's* deputy news editor. Follow him on Twitter @jjaron

Game

Disco Elysium

ZA/UM

PC, PlayStation 4 and 5, Xbox One, Series X and S

Jacob also recommends...

Game

Planescape: Torment

Black Isle Studios

PC, PlayStation 4, Xbox One, Nintendo Switch, Android, iOS

This cult classic role-playing game, also starring an amnesiac protagonist, is set across a strange fantasy multiverse and was a big inspiration for Disco Elysium.

ZA/UM

In *Disco Elysium*, other characters help you reinvent yourself

YOU wake up, unable to remember anything about your life or how you got here. This is the opening of so many video games that an amnesiac protagonist has become something of a cliché.

But Robert Kurvitz, lead writer and designer of *Disco Elysium* prefers to see it as an essential part of video game storytelling. "There's a promise of newness and being someone else, and for that the player needs to forget who they were," he told me when we spoke after the game's recent console release.

To be fair, *Disco Elysium* doesn't quite start with waking up. The game's first words are uttered by your ancient reptilian brain, which you engage in a conversation about whether to become conscious. Soon, your limbic system joins the exchange as you become increasingly aware of your surroundings, before waking up half-naked and hung-over. It is a unique and arresting beginning.

Stumbling out of your hotel room and speaking to the people you meet, it becomes apparent that you are a police detective trying to solve a murder, and you have been on a three-day bender, leading to complete memory loss.

Like many role-playing games, your character has a number of skills that determine your ability to perform tasks or unlock dialogue options. But while a traditional fantasy RPG might rate you for strength or magic, *Disco Elysium*'s skills are more unusual – what's more, they talk.

> **"Increase your Drama skill and you will find it easier to be inventive and spot when people are lying"**

Your Encyclopaedia skill, for example, might feed you bits of information about the vaguely Eastern European setting of the game, while Composure helps you read other people's body language and Electrochemistry pushes you towards indulging in alcohol and other addictive substances.

Kurvitz says the team wanted to avoid presenting the skill characters as the kind of intrusive voices that might be experienced by someone with, say, dissociative identity disorder. The skills are clearly facets of one personality rather than a mental cacophony. The team wanted to simulate the way the mind works through internal monologue, says Kurvitz.

This means that while the basic plot is about solving a murder, the game's real concern is the construction of identity. When playing, you gain points you can invest in skills, boosting the chances of success when you use them and further moulding your personality. Increase your Drama skill and you will find it easier to be inventive and spot when people are lying; boost it too high and you could become overly dramatic.

In addition to the skills, certain characters or experiences you come across in the game can trigger thoughts that you can choose to engage with and internalise. I found myself going for dialogue options dealing with art or creativity, which resulted in my Conceptualisation skill offering me the chance to be an "art cop".

The result is you can make some really strange choices about how your detective behaves, sending you deeper into *Disco Elysium*'s weird world. I have been taking full advantage, but Kurvitz says it has proved surprisingly difficult to get players to embrace these options.

To nudge people towards more interesting role playing, a message on the loading screen reassures you that making odd choices won't mean you fail in the game.

Perhaps the lesson is that when we are invited to reinvent ourselves, we tend to stick to the familiar. ▮

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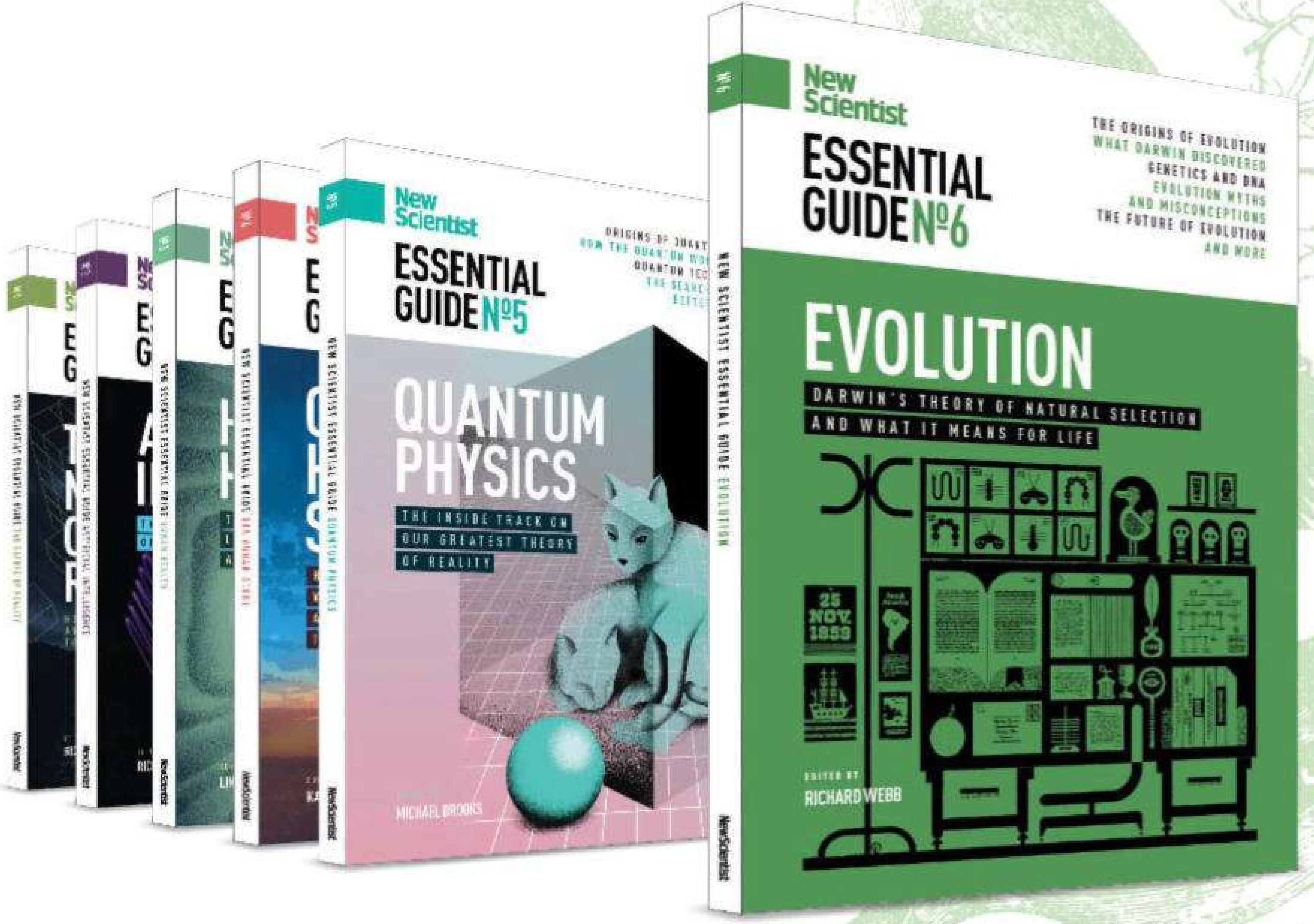

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The power of self-reflection

Greater self-awareness could be the secret to success. It is time to get to know yourself better, writes cognitive neuroscientist **Stephen Fleming**

AS YOUR eyes skip across the words on this page, it is likely that you are not only reading, but also thinking about yourself reading. Are the words clear? Can you concentrate? Do you have time to read this article now or are you feeling rushed?

Psychologists have a term for this kind of awareness of our own minds: metacognition – literally, the ability to think about our own thinking. Being able to turn our thoughts on ourselves is a defining feature of being human. But we often overlook the power it has in shaping our lives, both for good and ill.

The importance of good self-awareness can seem less obvious than, say, the ability to make mathematical calculations, or remember facts. Instead, for most of us, metacognition is like the conductor of an orchestra, occasionally intervening to nudge the players in the right (or wrong) direction.

Now, research from my lab and others is pulling back the veil on self-awareness, giving us a new-found respect for the power of the reflective mind. We have found ways to measure it, and can even watch it in action using brain scanners. What we have discovered is already suggesting a rethink in our understanding of conditions like dementia, but it has implications for us all. Boosting self-awareness can improve our decisions, open our eyes to fake news and help us think clearly under pressure. Just as a good conductor can make the difference between a routine rehearsal and a world-class performance, the subtle influence of metacognition can make the difference between failure and success in many aspects of life.

We rely on metacognition in all sorts of situations. When revising for an exam, for instance, you might reflect on how well you know the material, or whether you need to brush up on certain topics – metacognition about your memory. Or, on a visit to the opticians, you might be asked whether your vision is better or worse with a new pair of glasses – metacognition about your perception. More broadly, we can attempt to see ourselves through the eyes of others by taking a sort of third-person view of our personalities, skills and abilities.

Know your mind

The idea that self-awareness can be beneficial has a long history. Even before the ancient Greeks, thinkers have suggested that self-awareness is something to be striven for, and the essence of a life well-lived.

Even so, until relatively recently, metacognition wasn't considered a bona fide target of scientific inquiry. René Descartes relied on self-reflection to reach his famous conclusion "I think, therefore I am", noting along the way that "there is nothing that can be perceived by me more easily or more clearly than my own mind". This view left little room for the idea that self-awareness may be a brain process like any other, and equally prone to error or malfunction. Another French philosopher, Auguste Comte, thought the idea that self-reflection could be a mental process was nonsense, suggesting that it was simply impossible for a single brain to turn its thoughts upon itself. Self-awareness was therefore mysterious, indefinable and off limits to science.

We now know that the premise of Comte's worry is false. The human brain is no longer viewed as a single, indivisible organ. When we think about ourselves, particular brain networks crackle into life, and damage to or disease in these same networks can lead to devastating impairments of metacognition.

My lab at University College London focuses on understanding the mechanisms and neural basis of human metacognition. We are particularly interested in people's confidence in what they do and don't know. For example, in the middle of a pub quiz, you might ask your teammate whether they are sure they know

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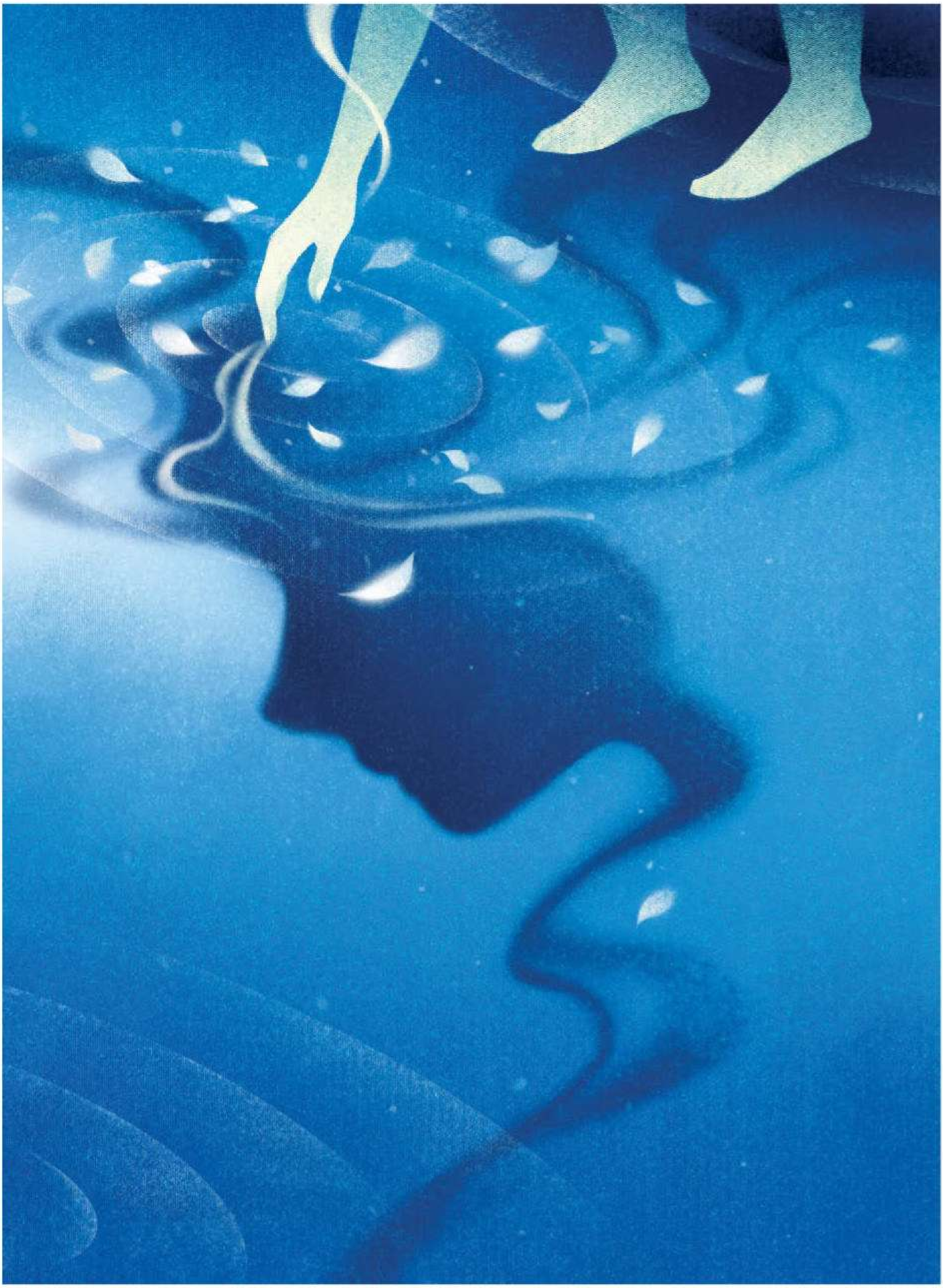

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the right answer (a confidence judgement about their memory). Or you may question whether a friend is certain it was really a celebrity they just spotted on a crowded high street (a confidence judgement about their perception). Having higher confidence when you are right and lower confidence when you are wrong leads to what psychologists refer to as having good metacognitive sensitivity, the extent to which our self-evaluations are sensitive to changes in our performance. This is subtly but importantly different from our general level of confidence, which is known as metacognitive bias. Many a pub quiz team has been hampered by someone with poor metacognitive sensitivity.

One way to measure these different facets of self-awareness in the laboratory is to use computer-based tests. In one task, we ask people to quickly decide which of two images contains a greater number of dots and then rate their confidence in this choice on a scale. By observing someone's confidence on multiple occasions and recording whether their subsequent answers are right or wrong, we can build up a detailed statistical picture of someone's metacognition. This also allows us to summarise their metacognitive ability as a set of parameters – like sensitivity and bias – known as their metacognitive fingerprint.

Psychologists have an increasingly detailed understanding of the brain circuits supporting this kind of self-knowledge too. The first hints that brain damage could lead to problems with metacognition came in the mid-1980s. Arthur Shimamura, then at the University of California, San Diego, was studying people who had amnesia due to damage to their temporal lobes, regions known to be important for memory. What was surprising was that some of his patients were unaware of having memory problems. In laboratory tests, they showed a striking deficit in metacognition: they were unable to rate how confident they were in getting the answers right or wrong. It turned out that those individuals with metacognitive problems also had damage to the prefrontal cortex, part of the brain involved in complex thought, decision-making and personality. More specifically, the damage affected the machinery that we now know is involved in building higher-level models of ourselves and others.

> **"The effects of brain damage on self-awareness may be surprisingly widespread"**

This fits with what we know from animal models, which indicate that there are exquisitely sensitive representations of confidence in similar brain areas to those damaged in those patients with metacognitive difficulties. One study showed that neurons in the rodent orbitofrontal cortex, which sits right at the front of the brain, track confidence in decisions about different odours, measured by how long a rat was willing to wait for a reward after making a correct decision. Another experiment from the same lab demonstrated that inactivating these circuits of neurons impairs metacognition, while the accuracy of odour decisions were unaffected.

In another study, my colleagues and I found that subtle structural differences in the prefrontal cortex of otherwise healthy people could predict their metacognitive fingerprint. Since then, by using functional MRI technology, my team has characterised how patterns of activation in different prefrontal subregions can predict how confident people feel in their decisions.

But aside from confidence, there is also a more elaborate aspect to metacognition, one that may be unique to humans and which allows us to consciously think about our own minds and the minds of others. This "explicit" form of self-awareness emerges between the ages of 3 and 4 years, continues to develop throughout adolescence and shares neural machinery with mentalising – our awareness of other people's mental states.

In fact, it now seems likely that the brain computations that elicit this explicit metacognition work as a "second-order" process that infers how confident we feel in our decisions or actions from a variety of cues, just as we infer what is happening in the minds of others from what they do or say. Because the brain circuity for explicit metacognition has a wide-angle lens, we have shown that it is able to pool information arising from different sources, tagging this information to create abstract estimates of our skills and abilities.

Your metacognitive fingerprint

Why are some people more self-aware than others? Studies show that metacognition is a relatively stable trait, so if you tested your metacognition today, it is likely to be similar if you do the same test again tomorrow. Strikingly, it also seems that metacognition is independent of IQ and general cognitive ability: your metacognition can still be in good form as long as you recognise you are performing badly at a task.

We still don't understand the origins of these individual differences, but one promising idea is that "explicit" metacognition is something we learn, based on feedback from our parents, teachers and social group. A genetic "starter kit" may establish forms of self-monitoring early in life and then our parents and teachers finish the job. But even in adulthood, these things aren't totally fixed (see main story), so this is one kind of fingerprint you can change.

JIM MONE/AP/SHUTTERSTOCK

Self-awareness can help us see through misinformation and fake news

What this research is telling us is that the human brain plays host to specific algorithms for self-awareness. In turn, these findings imply that the effects of brain damage on self-awareness may be more widespread than we think.

People with dementia may experience what clinicians refer to as anosognosia or loss of "insight" – being unaware of having cognitive problems. One way of understanding the causes of a loss of insight is that the disease has not only affected the brain circuits involved in memory and cognition, but also those responsible for maintaining normal self-awareness. If the capacity for metacognition becomes eroded, we may remain unaware of changes in our abilities and be unable to understand what we have lost. This may lead people to be reluctant to seek help, or take steps – such as writing lists – to guard against memory failure. And while lack of insight is acutely understood by clinicians to be a key feature of early dementia, metacognition isn't yet part of standard neuropsychological assessment for dementia.

Better decisions

As the ancient Greeks also correctly believed, accurate metacognition is critical for success in a range of endeavours. If a student is aware of what they do and don't know, they will be able to make good decisions about what to study next. These decisions may seem minor, but they can end up being the difference between passing or failing an exam.

Beyond the classroom, an accurate sense of confidence in our beliefs and decisions has been shown to increase people's ability to know when we might be wrong about issues ranging from politics to scientific theories, and provide the mental foundations for subsequent changes of mind. For instance, recent studies suggest that having an ability to engage in "cognitive reflection" – avoiding falling for an answer that initially feels right, but ends up being wrong – is an important component to resisting misinformation and fake news.

A final benefit of metacognition is that it helps us collaborate with others, and laboratory studies have shown that sharing information about confidence with teammates helps groups make better decisions.

Our metacognitive fingerprint emerges in childhood (see "Your metacognitive fingerprint", left), but even in adulthood, metacognition isn't set in stone and can be affected by stress or differences in mental health. In one study from my lab, we asked hundreds of people to answer questions about different mental health symptoms. From the pattern of their answers, we could see where each person fell on three core dimensions of mental health: their levels of anxiety and depression, their levels of compulsive behaviour and intrusive thoughts and their levels of social withdrawal. Where they sat along these dimensions predicted their metacognitive fingerprint. People who were more anxious and depressed had lower confidence but heightened metacognitive sensitivity, whereas those with compulsive behaviour and intrusive thoughts showed the reverse pattern.

A growing appreciation that metacognition relies on specific, malleable brain processes leads to a natural question: can we alter this neural circuitry to improve self-awareness? A deluge of self-help books and blogs encourage us to "find ourselves" and become more self-aware, but little attention is paid to how such change actually works, and rarely are the potential gains in metacognition assessed using objective tools. Questionnaire measures of self-awareness are less useful because, by definition, if you have poor metacognition, you are unlikely to be able to accurately report it. So the jury is still out on these self-help approaches.

The tools of metacognitive neuroscience are a better bet, as they help us directly target the mechanisms of self-awareness. Researchers at Trinity College Dublin, Ireland, have found that applying a kind of non-invasive brain stimulation called transcranial direct

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AMER GHAZZAL/SHUTTERSTOCK

Many a pub quiz team has been hampered by failures of metacognition

current stimulation to the prefrontal cortex can make older people more aware of their errors in simple tasks.

Drugs that increase levels of dopamine in the brain, and reduce levels of noradrenaline, have also been shown to benefit self-awareness, boosting metacognitive sensitivity without changing other aspects of performance.

In Japan, researchers at Advanced Telecommunications Research Institute International have developed "real time" brain scanning technology to train people to activate specific patterns of neural activity related to their levels of metacognitive confidence. After two days of this training, participants' metacognition was subtly altered, with people who were trained to boost "high confidence" brain patterns showing greater confidence in an unrelated task, and those trained to boost "low confidence" brain patterns showing the opposite change.

Brain stimulation and designer drugs are extreme ways of improving self-awareness. But more of us might be willing to invest time in simpler ways to train our metacognition. With this goal in mind, my lab has been working on tools to provide feedback on people's metacognitive judgements. We asked volunteers to spend around 20 minutes per day practising a simple perceptual discrimination, namely choosing which of two images was brighter. We found that those who were given feedback about their metacognition – whether their confidence judgements were accurate or inaccurate – had heightened metacognitive sensitivity after two weeks of training.

> **"In a culture of productivity, taking time to reflect is an optional luxury"**

Strikingly, these improvements in metacognition were also seen on a memory task that wasn't part of the training. In other words, having learned to boost metacognition on one task, people became more aware of whether they were right or wrong on a different one. This suggests that the training might be honing a more general system for self-awareness.

Another way of achieving similar effects may be through regular meditation. The impact of meditation on metacognition has only recently been explored. But initial results are encouraging. One study found that two weeks of meditation training could increase metacognitive sensitivity during a memory test. Other work has shown that expert meditators have greater metacognitive sensitivity compared with novices.

Perhaps the most useful way of improving self-awareness, though, is by recognising the situations in which it may become impaired. In a culture of efficiency and productivity, taking time to reflect on what we are doing seems to be an optional luxury. Paradoxically, we often most need self-awareness at precisely the times when it is likely to be compromised.

As the pressure comes on at work or when we are stressed by money or family worries, engaging in effective metacognition might reap the most benefits, enabling us to recognise errors or realise when we need to ask for help or change strategy. But laboratory studies have consistently shown a link between heightened stress and impairments in metacognitive sensitivity. For instance, giving people a small dose of cortisol leads to a temporary spike in this hormone that is sufficient to decrease metacognitive sensitivity compared with people given a placebo. Simply knowing a bit more about this fragility of self-awareness helps us adopt a more compassionate stance towards similar failures of metacognition in others.

If it were possible to systematically boost self-awareness, what might that feel like? One possible insight comes from work on lucid dreaming, where people are aware of being in a dream. Imaging studies have shown that when people become lucid, they recruit similar brain networks to those that support metacognition while awake.

I find it appealing that boosts to self-awareness in our daily lives might feel like the experience of becoming lucid in a dream – we might notice things we haven't noticed before in ourselves, in others and in our surroundings. These changes may permeate many aspects of our lives, because being self-aware is central to how we experience the world. The kind of consciousness we cherish – the kind that allows us to appreciate the smell of coffee, reflect on the beauty of a sunset or wonder whether our senses are being fooled by magic tricks – involves "meta-awareness", a state of knowing that we are conscious. ▮

Stephen Fleming is a cognitive neuroscientist at University College London. His new book is *Know Thyself: The Science of Self-Awareness*

DOUG GIMESY/NATUREPL.COM

Secrets of the platypus

Fresh light is being shed on the rise of mammals thanks to new clues from one of nature's oddest creatures, finds **Ibrahim Sawal**

ROLAND SEITRE/NATUREPL.COM

WHEN news reached London of a mole-like animal with webbed feet and a duck's bill, many people thought it was a hoax. It was the late 18th century, Britain had just begun colonising Australia and the strange creature had been spotted by no less a figure than David Collins, founder of New South Wales. However, when zoologist George Shaw at the British Museum examined sketches and specimens of the animal, he was sceptical. "It naturally excites the idea of some deceptive preparation by artificial means," he wrote.

Attitudes changed as more specimens arrived. In 1799, Shaw was the first to scientifically describe the creature, giving it the name *Platypus anatinus*, meaning "flat-footed duck". It was later referred to as the "paradoxical bird-snout" before being officially renamed *Ornithorhynchus anatinus*, meaning "duck-like bird snout". Today, most people just call it the platypus.

It took more than 80 years just to work out how this animal fits into the tree of life. Since then, biologists have gone even further and found that it possesses a range of features that mean it is among the most unusual creatures on Earth. But it isn't simply an oddity. As a mammal that shares many characteristics with birds and reptiles, the platypus holds the key to unlocking some fundamental evolutionary mysteries.

Now, geneticists have mapped its entire genome and are starting to understand how it came to be so strange – and what it can tell us about the origins of all mammals, including us. Even today, it turns out, the platypus has the ability to surprise.

The platypus is one of just five remaining species from an ancient group of mammals called monotremes that lay eggs rather than giving birth to live young, as other mammals do. The other extant monotremes, the four species of echidna, are equally strange (see "Echidna eccentricities", page 43). Found only in waterways across Tasmania and eastern Australia, platypuses are nocturnal and grow to about half a metre long. They may look like a mash-up of various animals, but, ecologically, they make sense. "They are exquisitely adapted to what they do," says biologist Jonathan Losos at Washington University in St Louis, Missouri. Their webbed feet, sprawled body and dense, waterproof fur are perfect for their semi-aquatic lifestyle. Their claws make them efficient diggers: they excavate tunnels around 5 metres long in riverbanks in which to live. And platypuses' distinctive, duck-like bills allow them to search for crustaceans and insects while swimming underwater with their eyes, ears and noses shut. "It has this amazing electroreception sense in its bill that can detect the muscular activity of its prey, even slight muscle twitches," says Losos.

These leathery bills are made of hardened gum tissues and, lacking teeth, platypuses use them to mash their food – sometimes employing stones to help crush harder items. Once swallowed, food travels straight from the oesophagus to the intestine: platypuses, together with their echidna cousins, are the only mammals without a stomach. These organs evolved some 450 million years ago, well before platypuses came along, and why these animals have lost theirs is unclear. One suggestion is that the shells in their diet are rich in calcium carbonate and would neutralise any stomach acids, making the organ redundant.

When they aren't hunting, platypuses rest. They can spend around 14 hours a day sleeping, including eight hours in rapid eye movement (REM) sleep, which is more than any other animal. That's odd, given that – in humans at least – REM sleep is associated with brain development and processing memories. Its abundance in platypuses suggests this type of sleep originated earlier in mammalian evolution than previously thought, says Losos, and that its functions may have evolved separately to meet the needs of different species.

A mysterious glow

A recently discovered platypus quirk is even more puzzling. Last year, researchers at the Field Museum of Natural History in Chicago, Illinois, reported finding that the animals glow in the dark. They had been trying to confirm this phenomenon, known as biofluorescence, in another species in their collection when they accidentally shone ultraviolet light onto a platypus specimen nearby. To their surprise, the fur emitted a blue-green glow. Biofluorescence is typically used for communication or camouflage, but that makes no sense in a nocturnal species. "Scientists are completely baffled by what this is all about," says Losos.

Then there is the platypus' peculiar reproductive behaviour. Like birds and reptiles,

Electrosensors in their bills allow platypuses to forage underwater with their eyes shut

> **The leathery bill, made of hardened gum tissue, is used to mash food**

monotremes have a cloaca, a single opening used for reproduction and excretion – which is where the name "monotreme" comes from. During the mating season, male platypuses fight for females, using poisonous spurs on their hind feet that deliver enough venom to kill a small animal or cause excruciating pain in humans. Females, meanwhile, use their claws to build a nursery. They dig a 30-metre-deep burrow, which they line with wet leaves for bedding. Once mated, they seal themselves inside, lay two eggs and hug these tightly underneath their tails to incubate them. In just 10 days, the butter-bean-sized babies, known as puggles, hatch. Their mothers don't have teats. "They kind of ooze milk out of their belly for the puggles to lap up," says Losos. The nursing young have teeth, but they lose these at around 4 months old when they leave their natal burrows and become independent.

Given that they lay eggs and produce milk, it is tempting to see monotremes as an evolutionary link between mammals and reptiles. In reality, it isn't that simple. To understand why, and to set the scene for the latest genetic discoveries, we need to go back to the first animals to conquer land: the tetrapods.

People often think that mammals evolved from reptiles, but this couldn't be further from the truth, says palaeontologist Elsa ›

Echidna eccentricities

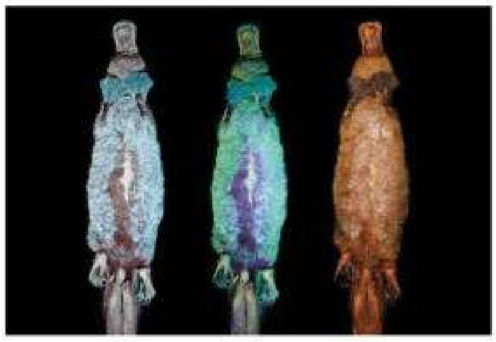
Australia and New Guinea are home to the four species of echidna, which are almost as weird as their fellow monotreme, the platypus (see main article).

- **Male echidnas have a four-headed penis. They use two heads at a time, swapping between pairs each time they have sex.**
- **A train of about 10 males, lined up nose to tail, can follow individual females around during the mating season.**
- **Females lay their eggs into a pouch on their bellies. Once hatched, the babies spend up to seven weeks there.**
- **A slow metabolism and one of the lowest body temperatures of any mammal mean echidnas can live for 45 years, which is far longer than most mammals of their size – they are about 50 centimetres long and weigh around 6 kilograms.**
- **Echidnas are covered in hedgehog-like spines, which are made from modified hairs. When threatened, they curl into a ball to protect themselves.**
- **They scoop up ants and termites with a 15-centimetre-long, sticky tongue.**

There are four species of echidna, which, along with platypuses, are the only living monotremes

SHUTTERSTOCK/KEN GRIFFITHS

> **“Other mammals generally have two sex chromosomes. Platypuses have 10**



The platypus’ pelt glows in UV light, which makes no sense for a nocturnal animal

Panciroli at Oxford University Museum of Natural History. Synapsids (mammals) and sauropsids (reptiles and birds) evolved separately after splitting from a single lineage around 310 million years ago. “Up to that point, they were neither reptiles nor mammals; they were tetrapods,” says Panciroli.

Early mammals lived alongside the dinosaurs, so faced stiff competition. “They hit on this absolutely fantastic way of life,” says Panciroli. Being small, nocturnal, shrew-like insectivores allowed them to thrive. These first true mammals belonged to an extinct order called morganucodonta. Later, other mammal groups evolved, but ultimately only one survived. Today, it consists of three lineages: monotremes, marsupials and, by far the largest lineage, the placentals, which are distinguished by carrying the fetus in the mother’s uterus into later stages of development. Marsupials and placentals jointly form a group called therians, which split from a common ancestor around 130 million years ago. Monotremes are older, originating some 180 million years ago (see diagram, right). “They’re this ancient group of mammals and they have such an amazing story to tell us,” says evolutionary biologist Vera Weisbecker at Flinders University, Australia.

Toothy ancestors

All this suggests that the first monotremes didn’t resemble those that are alive today, but instead looked similar to the shrew-like morganucodonts. Unfortunately, we have no fossil evidence of them, say Panciroli. Nor do we have fossils of intermediate forms. The oldest evidence of platypuses in Australia consists of fossilised skulls dating from just 15 million years ago. These are from an extinct species, which had teeth and grew to a metre long. A tooth from another extinct species has been dated to 62 million years ago, but it was living in what is now Argentina. That isn’t so surprising, given that South America and Australia were connected as part of the supercontinent Gondwana when monotremes first emerged. Clearly, they died out in South America following the break up of Gondwana, which began around 140 million years ago. Why they persisted in Australia, and why only one platypus species survives today, is still unknown. Panciroli predicts that the answer lies in yet-to-be discovered fossils of monotreme ancestors in South America. But Weisbecker thinks that the single piece of evidence from South America indicates that platypuses were rare in that region. “They may have just always sat in Australia,” she says.

Looking further back, the lack of fossil evidence is even more problematic. The first mammal was thought to have produced milk, laid eggs and possessed a cloaca. But there isn’t definitive evidence to confirm any of these assumptions. “It would be the holy grail if we could find a fossil mammal egg,” says Panciroli.

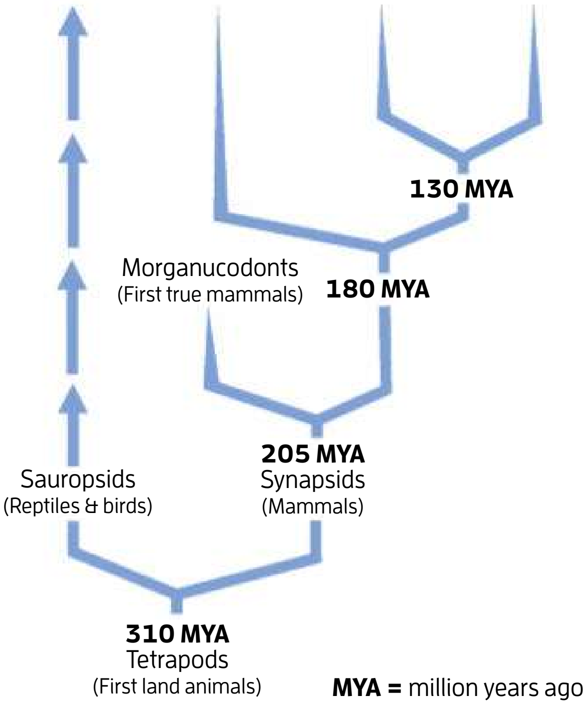
What we do have, however, is genetic evidence inside every cell of living monotremes – and now this evidence can be scrutinised. Earlier this year, Guojie Zhang at the University of Copenhagen, Denmark, and his team published a complete genome of the platypus, alongside the first fully sequenced echidna genome. “They hold a lot of the clues to understanding how the earliest mammals evolved,” says Zhang.

For a start, the researchers were able to put dates on key branches in the mammalian family tree. By comparing the monotreme genomes with those of other extant mammals, they were able to date the therian-monotreme split to around 187 million years ago – slightly earlier than previously estimated. The analysis also reveals that platypuses and echidnas went their separate ways around 55 million years ago. The two monotremes have since adapted to their own unique environments, yet are genetically very similar. For example, monotremes lost half of the eight genes related to tooth development just before the platypus and echidna lineages split. And many of the genes involved with digestion disappeared around this time too, suggesting this is when both echidnas and platypuses lost their stomachs as well as their teeth.

The genetic evidence also sheds light on the transition from egg laying to live births. The platypus genome contains genes for a protein called casein, which is seen only

Rise of the mammals

Monotremes weren’t the first mammals, but they do represent the oldest living branch of the mammalian tree, which is why platypuses and echidnas provide a window on mammalian evolution.



MYA = million years ago

|TOP: MARTIN/NORTHLAND COLLEGE;ANICH ET AL 2020

DOUG GIMESY/NATUREPL.COM

Male platypuses use a venomous spur (above) to fend off rivals while mating. The eggs (below) are laid in burrows, which the young (left), known as puggles, leave after 4 months

in mammals and is crucial for the production of mammalian milk. "So platypuses produce similar components to the milk we produce," says Zhang. This suggests milk production must have developed in the common ancestors of all modern mammals more than 187 million years ago, he adds. Platypus milk has a unique ingredient, however. The genome reveals that it contains antibacterial proteins, perhaps to help protect puggles from pathogens while they are in their natal burrows.

The end of eggs

The ability to produce milk would have meant that early mammals didn't need to lay eggs capable of entirely sustaining their developing offspring, as other egg-laying animals do. The platypus genome reflects this. Reptiles and birds have three genes for proteins called vitellogenins, which are instrumental in the production of the egg yolk. Humans and all other therian mammals lack these genes. But platypuses and echidnas still have one of them, and continue to lay eggs by virtue of the vitellogenin this gene produces. The other two genes seem to have been lost around 130 million years ago, says Zhang. In which case, the last gene must have been lost later in therian mammals and the practice of giving birth to live young must have evolved after they split from the monotremes.

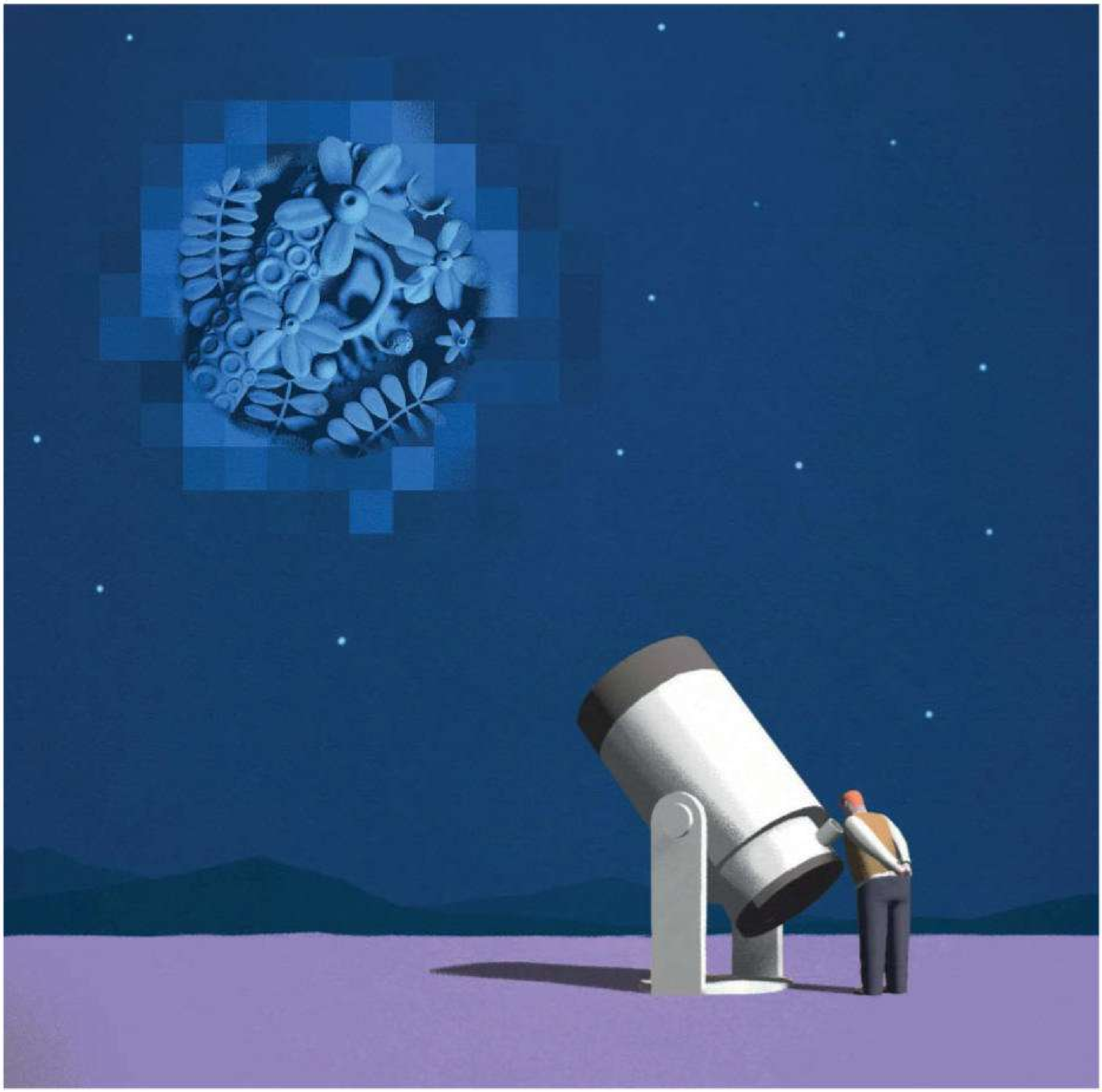
Platypus sex chromosomes tell another intriguing story. Other mammals, including humans, generally have two of these, X and Y – paired as XX in females and XY in males. Platypuses have 10 – occurring as $X_1X_1X_2X_2X_3X_3X_4X_4X_5X_5$ in females and $X_1Y_1X_2Y_2X_3Y_3X_4Y_4X_5Y_5$ in males. Looking more closely at the sex chromosomes in a male, the researchers found that the X_1 chromosome had similar genetic sequences to those of the Y_1 chromosome. Y_1 was similar to X_2, and so on until Y_5 matched back to the X_1 chromosome. "We can predict they formed a ring in the monotreme ancestor," says Zhang. What this says about other early mammals is unclear, but such chromosomes have never been found to occur normally in a living animal. This ring must have broken into smaller pieces of X and Y chromosomes over the course of mammalian evolution, and the system of two sex chromosomes that we have later evolved.

That isn't all. After comparing the platypus sex chromosomes with those of other animals, the researchers concluded that they show more parallels with those of chickens than humans. "It doesn't have any hallmarks with our human XY chromosomes," says Zhang. "The five pairs of XY chromosomes are more like the ZW chromosomes of birds." Platypuses have several genetic sequences that match those found in birds, whereas the sex chromosomes of therian mammals and birds have no genes in common. This overlap with birds could mean that the platypus may still contain genetic sequences inherited from the early tetrapod species before birds and mammals diverged from them.

Zhang's genome analysis has expanded our understanding of platypus and mammalian evolution. "Monotremes are that magical third coordinate that gives you the proper location to find your way through the evolution of mammals," says Panciroli. The challenge, however, is to work out which aspects of platypus biology are really representative of the past. Although they possess ancient characteristics, we shouldn't think of them as living fossils, says Panciroli. "They are evolutionarily distinct."

Sadly, platypus numbers are declining as their habitats become increasingly damaged. They are now classed as near-threatened by the International Union for Conservation of Nature. Echidnas and the platypus are the only monotremes left, the end of an evolutionary line that goes back to before the dinosaurs. "It would be a shame if we lost them," says Losos. "There's nothing else like them out there." ▮

Ibrahim Sawal wrote this feature while working as an intern at *New Scientist*. He tweets at @ibicus3_



STUART MCREATH

Far-flung flora

A new way to decipher the light from distant worlds could give us unmistakable evidence of extraterrestrial photosynthesis, and maybe alien plants, finds **Colin Stuart**

PALM trees with crimson fronds sway in the breeze as waves lap at a shore warmed by an alien sun. Rock pools are lined with something kelp-like, blue lichens carpet every boulder and strange flowers spring from the dunes beyond.

Astronomers are in little doubt that a plant-filled planet exists beyond our solar system, even if they aren't entirely sure what the flora would look like. The universe isn't short of worlds that could host life. Extrapolating from the 4000 or so exoplanets we have identified so far, NASA researchers recently estimated that there could be around 5 billion habitable planets in our galaxy alone. The challenge is to show that one of them is indeed inhabited.

A small army of astronomers are devoted to the task, scouring light that passes through alien atmospheres for hints of bacteria or plants. It is a vibrant enterprise, but at best it provides circumstantial evidence. Astronomers have long known there is a better way – that searching for light reflected off the surface of an exoplanet offers greater chances of success. "It gives you the chance to look directly for living material itself," says William Sparks at the SETI Institute in Mountain View, California.

The problem was that it was impossible. But recent breakthroughs suggest we can finally tease out the portion of reflected light that would betray unambiguous signs of photosynthesis from other worlds. The telescopes we need are already under construction. In the meantime, the race is on to figure out just what to look for. Astronomers are now working to identify the reflected signatures of verdant vegetation on Earth as a guide to what they should seek on alien worlds.

When it comes to searching planets beyond our solar system for signs of life, astronomers have focused primarily on atmospheric biosignatures. There is a huge amount of oxygen in Earth's atmosphere, for example, produced by plants, trees and photosynthesising microorganisms adrift on the open ocean. It is a similar story with methane, which is produced by bacteria, rotting vegetation and ruminant beasts.

But teasing out traces of these gases on other worlds is fraught with difficulty. As light from the host star passes through the planet's atmosphere, different colours are absorbed depending on which gases are present. The resulting gaps in the spectrum we see from Earth tell us what the planet's atmosphere is made of. You need a big telescope to separate the light into its constituent parts with sufficient resolution, however, and for the most part that means you are limited to ground-based instruments. The snag there is that the starlight then has to pass through Earth's atmosphere, too, where terrestrial oxygen leaves its own mark. This is just one of many ways to get a false positive.

"We've been waiting two decades for a breakthrough like this"

We could remove the complicating effects of our atmosphere with a large space telescope like the James Webb observatory, due to launch in October. Even then, though, these signatures are far from clear cut. Oxygen could be coming from water being broken into its constituent parts by sunlight, for example, and methane could be billowing from volcanic vents rather than decaying plants. "The growing consensus is that we won't be certain of anything we find," says Sara Seager at the Massachusetts Institute of Technology. "For every scientist who can find a way for life to produce that gas, there's another who can find a way it can be produced without life."

Twenty years ago, Seager was among the first to explore an alternative way to study exoplanets using light. To understand it, think about light as an electromagnetic wave. Usually the light we encounter from the sun or a light bulb is unpolarised – the wave vibrates in various directions. Polarised light, on the other hand, is restricted to vibrating only in certain directions. It just so happens that starlight is polarised when it reflects off a planet's surface, and the way it is polarised should contain clues about exactly what is doing the polarising – including life.

This is what attracted Seager and others to polarimetry, or the measurement of polarised light. Whereas atmospheric biosignatures are ambiguous, signatures coming directly from the surfaces of alien worlds – encoded in polarised light – would provide more reliable clues.

Polarised light might make it possible to nail down the presence of liquid water on other planets, for example. Looking for signatures in atmospheres will only show water as vapour in the highest layers of the air. Polarimetry can detect clouds of liquid water droplets and maybe even oceans, as sunlight glinting off water is strongly polarised. "You can even analyse wind speeds and wave heights," says Michael Sterzik at the European Southern Observatory in Chile, because they alter the way the ocean reflects newly polarised sunlight back into space. "Polarisation is the most promising technique for characterising Earth-like exoplanets," says Sterzik.

But it might get even better than that. In the best-case scenario, polarised light could dazzle us with unmistakeable evidence of biology. This would come in the form of signature oscillations in light waves that can only be caused by the chemical structure of the chlorophyll molecules involved in photosynthesis, the process by which plants and some bacteria on Earth convert sunlight into sugars.

The catch is that polarised light reflecting off distant planets is extremely difficult to observe. For starters, it is dimmer than light coming directly from a star via an

Lichen on other planets would twist light in a particular way

CHRIS MATTISON/NATUREPL.COM

atmosphere. Then there is the fact that only one per cent of the reflected light is polarised, making the signal fainter still. "We've tried several times and failed," says Seager. "I never thought we'd see it."

Now, finally, we have. In January, two separate teams announced they had detected polarised light from an exoplanet. A group led by Rob van Holstein at Leiden University in the Netherlands was first, using the Very Large Telescope in Chile to capture polarised infrared light from a disc of dust and gas surrounding the exoplanet DH Tau b. Less than a fortnight later, a team led by Jeremy Bailey at the University of New South Wales in Australia announced the detection of polarised starlight reflected off 51 Pegasi b – the first exoplanet discovered around a sun-like star.

Neither planet is Earth-like – both have masses greater than Jupiter. But the detections are a big breakthrough. "We've been waiting two decades for this," says Bailey.

The challenge now is twofold. First, astronomers have to refine the detection techniques so that we can repeat the feat for smaller, Earth-like planets. The smaller a planet and the further away it is from its star, the fainter the light reflected off its surface will be. Second, and most importantly, we have to figure out what signatures plant life would leave in any polarised light we can detect.

That isn't going to be easy, but polarimetry does at least make it possible because there is something unique about the way life – and plants in particular – polarise light. The reflected light from clouds and oceans is linearly polarised, meaning the wave vibrates in line with the direction in which it is travelling. Plants, on the other hand, impart circular polarisation: the reflected light wave rotates in a plane at right angles to the direction of travel.

There are non-living things that can produce this signal, but the chlorophyll in plants does it in a unique way. Whether the rotation of polarisation is clockwise or anticlockwise depends on the chirality, or handedness, of the molecules doing the polarising. Look at your hands for a moment. They are mirror images of one another, but you cannot perfectly superimpose one on top of the other. This is what chiral means.

In chemistry, molecules also exist in similar left-handed and right-handed orientations. When non-biological materials impart circular polarisation, each handedness is produced in equal quantities. But life on Earth only uses amino acids that are left-handed and sugars that are right-handed. This exclusivity is called homochirality and it is something Sparks thinks we could see in the polarised light from an Earth-like exoplanet. Seeing at least a 60:40 split between the two orientations would be enough to suggest life, he says, as there is nothing else we know of that could be behind a divergence from 50:50. "It's a more unique biosignature," says Sparks.

It was long thought that circular polarisation signals would be thousands of times weaker than their linear counterparts, and therefore

> "There is something unique about the way life, and plants in particular, polarise light"

Black grass, blue leaves

If there are plants on other planets, what might they look like? We don't know. But astrobiologists have offered some informed speculation.

Plant life on Earth evolved to suit the conditions provided by the unique properties of our sun and our planet's atmosphere. Most of the light that reaches Earth's surface is in the red part of the visible spectrum, which is thought to explain why chlorophyll, the cellular machinery behind photosynthesis, absorbs mostly red light and reflects green. That is why plants are green.

Evolution is very sensitive to environment, so plant life on worlds unlike ours could be quite different to the flora we know. Many of the exoplanets that we consider the most habitable orbit red dwarf stars, which are smaller and cooler than our sun. Researchers have speculated that plants in these systems could have photosynthetic pigments that render their leaves red, yellow, purple or even blue. It all depends on the dominant colour of the light hitting a planet's surface.

If the host star is particularly dim or distant, plants might even appear black to human eyes because they would need to absorb more parts of the visible spectrum to photosynthesise. Researchers have also suggested that plants on worlds subject to serious solar flares might secrete some sort of natural sunscreen.

far too faint to see. But Sparks has recently called that assumption into question. His experiment involved shining unpolarised light at cultured bacteria that photosynthesise without producing oxygen. In October 2020, Sparks and his colleagues showed that up to 1 per cent of the light reflected off these bacteria was circularly polarised – about the same as the linear polarisation signal. "It's stronger than we thought," he says.

In a further twist, they found the signal was highest when the bacteria broke down and released raw pigments into their environment. "It means we're not looking for life," says Sparks. "We're looking for death." The result backs up an earlier find from Lucas Patty at the Institute of Plant Biology in Hungary, who is one of Sparks's co-authors. In 2019, he showed that the circular polarisation signal linked to brown algae can be as high as 2 per cent.

But even if the polarisation signal from alien photosynthetic life is stronger than we would expect, would we really be able to detect it across the vast swathes of space? "There's no denying it's going to be difficult," says Sparks. "We're just beginning to understand the interaction between light and life."

Fortunately, we live on a perfect test planet. Sterzik has been using the Very Large Telescope to look at the light of our own planet reflected back to us by the moon, known as earthshine. This includes some of the polarised light bouncing into space from plants on Earth, and Sterzik was able to distinguish visible areas of vegetation in the signal. "It is surprisingly straightforward to use polarimetry in this way," he says.

Sterzik also noticed something else that surprised him. "We saw more polarisation in the red part of the spectrum than expected," he says. Leaves of deciduous plants are particularly good at reflecting light at the crossover between the visible and infrared parts of the spectrum. This so-called red-edge is also a potential biosignature. If it turns out to be even stronger when observed by its polarisation, that could offer us another robust way of looking for plants on distant planets.

But we can do better still. With earthshine, you have to disentangle the effect of the lunar surface on the signal. Strapping a polarimeter to the International Space Station could get around this issue, but you still can't see the whole planet at once. "We can't do this properly until we step away from the Earth and take a selfie from the moon," says Dora Klindžić, part of the team at Leiden University involved in spotting the polarisation signal from DH Tau b.

Klindžić is the driving force behind the Lunar Observatory for Unresolved Polarimetry of Earth (LOUPE) mission. Last November, she outlined her idea to piggyback a polarimeter onto a future trip to the moon and drink in the polarised light from Earth as it hits the lunar surface. Rather than capturing a beautifully focused image of Earth, like the famous ones taken by the Apollo astronauts, LOUPE would cram all of Earth's light into a single, unresolved pixel. The idea is to mimic the way we see the light from distant exoplanets.

ESO/Y.BELETSKY

The Very Large Telescope in the Atacama desert, northern Chile

Moonshot

By untangling the polarisation signals LOUPE detects, we can match them to known features of Earth's biosphere. That way, when we turn to the wider universe, we know exactly the kind of polarisation biosignatures we are looking for. There is a chance it could help us tell the difference between signatures from photosynthetic bacteria and more conventional plant life – something that both Sparks and Patty say is currently beyond us.

We shouldn't have to wait too long, either. "Within a year or so we may have the first prototype to test," says Klindžić. With the moon the subject of growing interest both from government space agencies and private companies, there will be no shortage of missions on which to hitch a ride.

The other big project in the pipeline is the Extremely Large Telescope, which is currently under construction in the Atacama desert in Chile. Its primary mirror will be a whopping 39 metres in diameter – compared with 8.2 metres at the Very Large Telescope – and it will come equipped with a next-generation spectropolarimeter. "I definitely believe that detecting rocky exoplanets and characterising them is possible with the ELT," says van Holstein.

All of which adds yet more impetus to the race to understand how life on Earth – and plants in particular – polarise sunlight. "What we're doing now is something we're really going to cash in on once the next generation of telescopes comes out," says Klindžić. It could well herald the dawn of a new era in our search for life elsewhere, one that gives us the best chance yet of answering that age-old question: are we alone in the universe? ▮

Colin Stuart (@skyponderer) is an astronomy author and speaker based in Surrey, UK. Get a free ebook at colinstuart.net/ebook

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The back pages

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Twisteddoodles for *New Scientist*
Picturing the lighter side of life p56

The science of cooking

Cooking after covid-19

If your sense of smell has been affected by illness, you can still make food interesting using the basic tastes, says **Sam Wong**

Sam Wong is social media editor and self-appointed chief gourmand at *New Scientist*. Follow him @samwong1

What you need

To serve two:

2 portions of noodles
2 tbsp peanut butter
1 tbsp sesame paste or tahini
2 tbsp soy sauce
1 tbsp rice vinegar or lime juice
1 tsp sugar
Chilli oil, to taste
A handful of roasted peanuts
Crunchy veg, such as cucumbers, peppers or radishes

The science of cooking appears every four weeks

Next week

Stargazing at home

OKSANAKIIAN/GETTY IMAGES

FOR many of us, food has been one of the most dependable pleasures in a year when so many normal activities have been put on hold. It seems particularly cruel that a common, lingering symptom of covid-19 is an altered sense of taste and smell, with studies finding that between 40 and 85 per cent of people with the illness experience some loss of these senses.

The virus that causes covid-19 attaches to ACE2 proteins in the olfactory epithelium, the tissue inside the nose where our smell receptors are located. Once the virus enters these cells, it triggers inflammation, and researchers think the inflammatory reaction causes olfactory neurons to lose their cilia, the projections on their surface that help them capture aroma molecules.

The cilia usually grow back once the infection clears up, and for most people, the loss of smell (also known as anosmia) lasts about 10 days or so. But some people don't fully recover this ability for months, and it can have profound effects on their mental health. It is unclear why this symptom persists for so long, or whether these people will ever get their sense of smell back.

Thankfully, there is advice available for people affected by smell loss that can help them get more enjoyment from food. Anosmia is also a common side effect of cancer treatment, and Life Kitchen, a not-for-profit cookery school, was set up to help those affected. It has now published a free cookbook, *Taste & Flavour*, specifically for people who have been affected by covid-19.

Drawing on research by Barry Smith at the School of Advanced Study, University of London, and others, the team at Life Kitchen has learned that there are some distinctive features of anosmia and parosmia – distorted smell – related to the coronavirus. Those affected frequently find certain foods, such as meat, eggs, onions and garlic, particularly revolting.

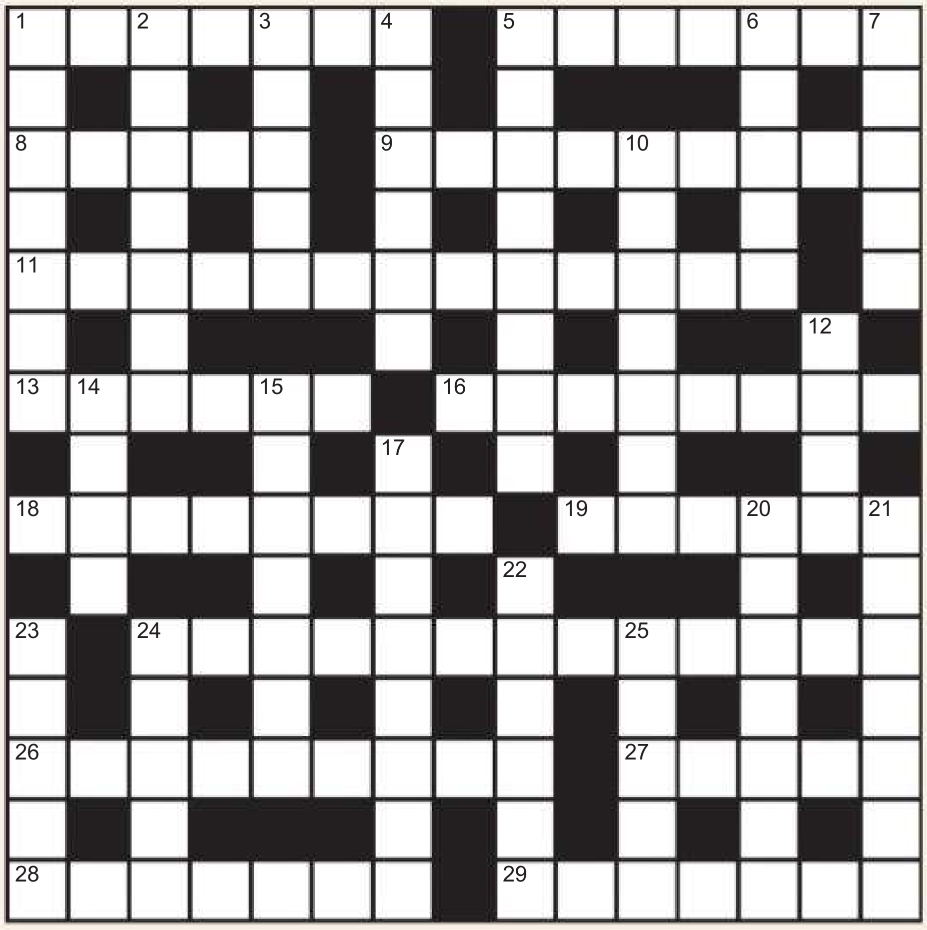
What can they still enjoy? Most people still sense the basic tastes we detect with the tongue: sweet, sour, salty, bitter and umami. They feel the heat of chillies, coolness of mint and pungency of wasabi, sensations mediated by the trigeminal nerve. And a variety of textures in a meal can help make food more interesting.

The recipes in *Taste & Flavour* are designed to create pleasure from food by stimulating the still-working senses. My suggestion is peanut and sesame noodles, a dish that offers umami, salty and sour tastes, heat from chilli and soft, creamy and crunchy textures.

Mix the sauce ingredients and cook the noodles according to the instructions on the packet. Add some noodle cooking water to the sauce, a little at a time, until you get a pourable consistency. Mix the sauce into the noodles and top with chopped peanuts. For extra crunch, add salad vegetables, such as cucumber, peppers or radishes. ▮

These articles are posted each week at newscientist.com/maker

Quick crossword #82 *Set by Richard Smyth*



Scribble zone

Answers and the next cryptic crossword next week

ACROSS

1 Remained stationary in mid-air (7)
5 Plant also called a clubmoss or quillwort (7)
8 Greenfly, for example (5)
9 Obstruction; closing (9)
11 Kitchen appliance invented by Percy Spencer (9,4)
13 Assembled at the site of manufacture (6)
16 Steroid hormone (8)
18 Bacteria genus, harmful to humans (8)
19 See 26
24 William ___, illustrator known for his elaborate machines (5,8)
26/19 Site of a 1979 nuclear accident (5,4,6)
27 Yeasts, moulds and mushrooms, for example (5)
28 ___'s Demon, a thought experiment relating to the second law of thermodynamics (7)
29 Rich in a common carbohydrate, like rice or cassava (7)

DOWN

1 Coloured data visualisation (4,3)
2 Means of transport (7)
3 Signalling and communication technology (5)
4 Asian cedar (6)
5 Of a missile or radar system, secured to a target (6,2)
6 Abnormally folded protein (5)
7 One who contributes blood, eggs or an organ, perhaps (5)
10 Positive ratings on social media (2-5)
12 Tethys, Io or Triton, say (4)
14 Water bird in the family Rallidae (4)
15 Mean, median or mode (7)
17 Localised die-off of aquatic animals (4,4)
20 As (7)
21 Measurement expressed in kilograms per metre cubed (7)
22 Lower part of the gastrointestinal tract (6)
23 Fact; statistic (5)
24 Marmot-like African mammal (5)
25 Latin prefix meaning "beneath" (5)

Our crosswords are now solvable online
newscientist.com/crosswords

Quick quiz #100

1 The production of fruit without fertilisation, thereby making them seedless, is known as what?

2 What does ENIAC stand for?

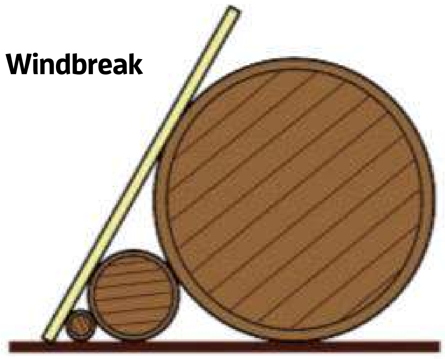
3 Roughly how long did it take NASA's New Horizons probe to reach Pluto?

4 How many geologic periods made up the Palaeozoic era?

5 Which element has an atomic number of 100?

Answers on page 55

Puzzle
set by Barry R. Clarke
#112 A muse in barrels



In Sweden, at the Barrel Olaf storage yard, a small, cylindrical wooden barrel with a diameter of 20 centimetres has been placed against a straight windbreak inclined at 60 degrees to the horizontal. Two more, larger barrels have been pushed up against it so that each touches any neighbours and the windbreak (as shown).

What is the diameter of the third barrel?

Answer next week

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Pull of gravity

What could happen to change gravity on Earth as we know it?

Hillary Shaw
Newport, Shropshire, UK
There are several ways that surface gravity on Earth could change. We wouldn't like most of them.

If a mini black hole collided with Earth and didn't pass straight through, it would sink to the planet's centre. Gravity would soar as the entire planet is pulled into the hole. It would probably get very hot too, so no one would survive to see the final spaghettification as we got within a few kilometres of the hole, when we are pulled apart by intense gravity gradients.

Alternatively, Earth's gravity could dwindle to zero in a possible future event known as the big rip, when the universe has expanded to the point where everything, even subatomic particles, are trillions of kilometres apart.

Then there are scenarios in which an intensely energetic subatomic collision disturbs our cosmic "false vacuum" and resets everything to a lower-energy state. Or our universe could collide with another one, provoking a sudden change in physical properties. This could include a changed gravitational constant that rips outward from the initial event at the speed of light, so we would never see it coming.

> **"No one would survive to see the final spaghettification, when we are pulled apart due to intense gravity gradients"**

Finally, and most benignly, gravity here changes by a minuscule amount every day as our planet gains some space dust and loses gases from the upper atmosphere. But as the mass of Earth is currently 6 × 10^{24} kilograms, you don't need to reset your bathroom scales anytime soon.

Graham Smith
Werribee, Australia
Over the next few billion years, Earth's gravity will change by tiny amounts because of several events. As the sun expands, the oceans will boil off into space, reducing the planet's mass and therefore cutting the force of its gravity.

But Earth's core will also cool, so the planet will experience thermal contraction. As the radius of the planet decreases, the force of gravity on the surface will increase because, for a sphere, the force of gravity on the surface is inversely proportional to the radius squared. But if Isaac Newton and Albert Einstein were wrong about gravity and it turns out that the universal gravitational constant isn't, in fact, constant but changes on a timescale of billions of years, then all bets are off.

Richard Glover
London, UK
The only thing we know that affects a body's gravity is the amount of mass it contains. So to change Earth's gravity we would need to add or remove mass from our planet. But to make a noticeable change, we would need to move vast amounts of material.

Another factor is the rate at which our planet rotates. At the equator, where the speed is greatest, centrifugal force slightly counterbalances gravity, making you lighter than at the poles.

So there are a couple of ways to change Earth's gravity, but not practical ones. Which is probably just as well!

Mike Follows
Sutton Coldfield, West Midlands, UK
The close approach of a massive celestial body such as a neutron star would distort the pull of gravity on Earth's surface.

If it were eight times as far from Earth as our moon is, people on the side nearest to the star would feel as if gravity had been reversed, acting upwards instead of downwards. They would be able to walk on the ceiling as if it were the floor, provided the building hadn't already disintegrated. Meanwhile, people on the other side of Earth would feel heavier.

If the neutron star were to get much closer, its force of gravity would pull people and loose objects from the planet's surface.

SHUTTERSTOCK/CHAMPION STUDIO

Is it possible for a loud sound to be so brief that we can't hear it?

This week's new questions

Loud but unheard **Is it possible for a sound to be loud but so brief that it can't be naturally heard by a person?** ***Jed Stephens,*** *Keighley, Yorkshire, UK*

Milky microbes **Where did the bacteria that turn milk into yogurt come from? Have they evolved since humans started to store milk? If so, what did their forebears do?** ***Martin Hillmann****, Gattonside, Scottish Borders, UK*

Taste the smell

Why do some things, like fresh coffee, smell better than they taste?

Lewis O'Shaughnessy
Nottingham, UK
Smell and taste are closely linked, but there are many differences. The flavour and smell of coffee aren't the result of a single chemical, but a complex cocktail of more than 1000 compounds.

The exact balance of flavour can be adapted by varying a range of factors, including the beans, how long they are roasted and specifics of the brewing method such as grind size, temperature and pressure. This affects how many of the harder-to-extract flavours are present in the final cup of coffee.

Of these different flavour compounds, some will easily vaporise, allowing them to diffuse through the air and enter your nose where you smell them. Others, often those that are much larger, need higher temperatures

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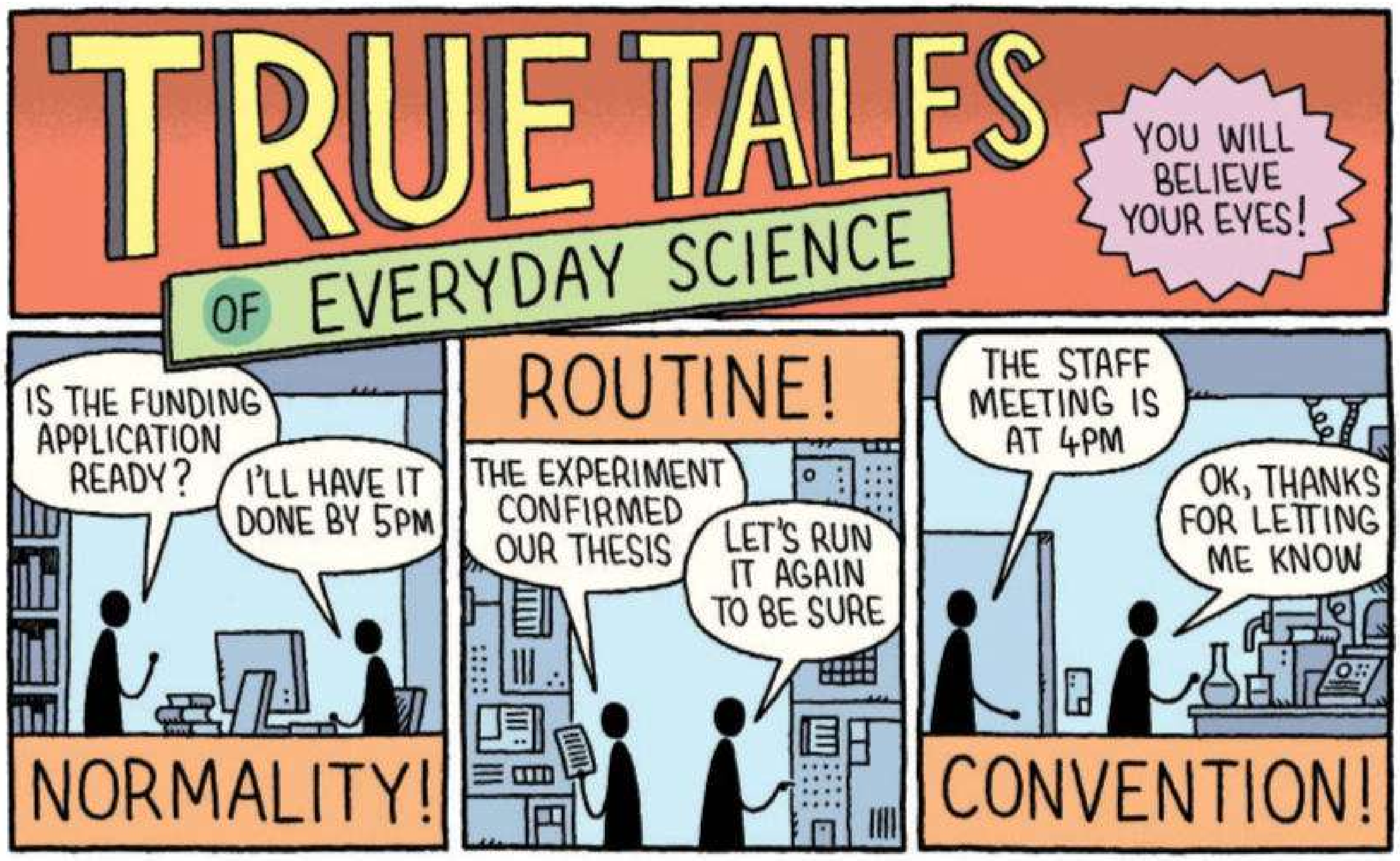

TRUE TALES OF EVERYDAY SCIENCE
YOU WILL BELIEVE YOUR EYES!
IS THE FUNDING APPLICATION READY?
I'LL HAVE IT DONE BY 5PM
NORMALITY!
ROUTINE!
THE EXPERIMENT CONFIRMED OUR THESIS
LET'S RUN IT AGAIN TO BE SURE
THE STAFF MEETING IS AT 4PM
OK, THANKS FOR LETTING ME KNOW
CONVENTION!

to vaporise and so you will smell them less or not at all.

When you drink the coffee, you taste all of the different flavour compounds at once, whereas when you smell it, you experience them in a different composition and some won't be present at all.

David Cox
Adelaide, Australia
The dominant taste in coffee is bitter. Humans have an innate aversion to bitter taste because of associations with alkaloid toxins that protect some plants from being eaten. However, through conditioning, many people learn to like coffee's bitterness because of the "benefits" of the caffeine in it.

But coffee is so much more than taste and possesses hundreds of volatile flavour compounds that humans perceive as pleasant aromas – its "chocolate notes", for instance. It is a bigger challenge to overcome an aversion to bitter foods that have no immediate benefit such as bitter vegetables, particularly brassica types such as cabbage and broccoli.

> **"Coffee can smell great yet taste disappointing. It is the reverse for cheeses that smell like old socks yet taste very nice"**

Kevin Privett
Llandough, Cowbridge, UK
In his book *Gastrophysics*, psychologist Charles Spence discusses the two different ways in which we smell. The orthonasal route picks up external aromas from the environment and the retronasal route picks up aromas pulsed out of the back of the mouth into the nose when we are eating or drinking.

Spence mentions the great smell of freshly ground coffee versus the often disappointing taste when we drink brewed coffee, and the reverse in the case of ripe cheeses that can smell like old socks, yet taste very nice.

Normally, we are good at predicting the retronasal flavour of food based on the orthonasal smell. However, in the case of coffee, it seems that there are far more volatile aromatics in the air above the ground beans than in the final brew.

Sticking power

How does porridge manage to stick to non-stick pans?

Alexander Fedorchenko
Czech Academy of Sciences, Prague
The reason porridge sticks to non-stick pans is explained by the physics of fluids, specifically the thermocapillary effect. Earlier this year, a colleague and I explained, through experiments, the phenomenon of food sticking to a pan while frying (*Physics of Fluids*, doi.org/f8pq).

When cooking porridge, water moves to the periphery of the pot, exposing a dry spot in the centre. This means the centre of the pan overheats and the dry cereal sticks to the pan. To prevent this, turn the heat to minimum after the porridge boils and stir it continuously. Bon appetit. ▮

Answers

Quick quiz #100
Answers

1 Parthenocarpy
2 Electronic Numerical Integrator and Computer. It was the first general-purpose computer
4 Nine-and-a-half years.
3 Six: the Cambrian, Ordovician, Silurian, Devonian, Carboniferous and Permian periods
5 Fermium

Cryptic crossword #56 *Answers*

ACROSS 1 Oops, **3** Bechamel, **8** Burnish, **10** Paper, **11** Theatre box, **14** Nature, **15** Calico, **17** Solar panel, **20** Fauna, **21** Messier, **22** Skeleton, **23** Plot

DOWN 1 Orbiting, **2** Permeate, **4** Echoed, **5** Hippocampus, **6** Mope, **7** Lyre, **9** Interpolate, **12** Biennial, **13** Noble rot, **16** Warm to, **18** UFOs, **19** Cube

#111 Eclair-voyance
Solution

Amy had the 6 of spades and Tom had the 5. When Tom first says he doesn't know whether he will win, he can't have either the 2 or the 10, or he would know.

Amy picks up on this, so "Same goes for me" implies that she doesn't have the 2 or 10, but also that she doesn't have the 3 or 9, for then she would know whether she had won or lost.

Tom's admission that he still doesn't know means he has neither the 3 or 9, nor the 4 or 8. So he must have the 5, 6 or 7.

Amy still not knowing means she has the 6, the only card for which the outcome would still be unsure. Realising this, Tom admits defeat, because he has the 5.

Greenfinger

No finer monument graces central London's skyline than the very large, very hush-hush building just by Vauxhall Bridge that houses Her Majesty's Secret Intelligence Service. From that edifice emerges the news that, besides cat-stroking villains plotting world domination from their volcano lairs, the spooks of MI6 now have climate polluters in their sights.

Climate change is the "foremost international foreign policy agenda item for this country and for the planet", the head of the UK spy agency, Richard Moore – known as "C" to his friends – told Times Radio. This is why MI6 has started "green spying" on other nations to make sure they are playing fair and keeping to their climate change commitments.

Not before time. The world is hot enough. Carbon is forever and we don't want to fry another day. No time to divest if we are to avoid skyfall... you get our drift.

Ugly ducklings

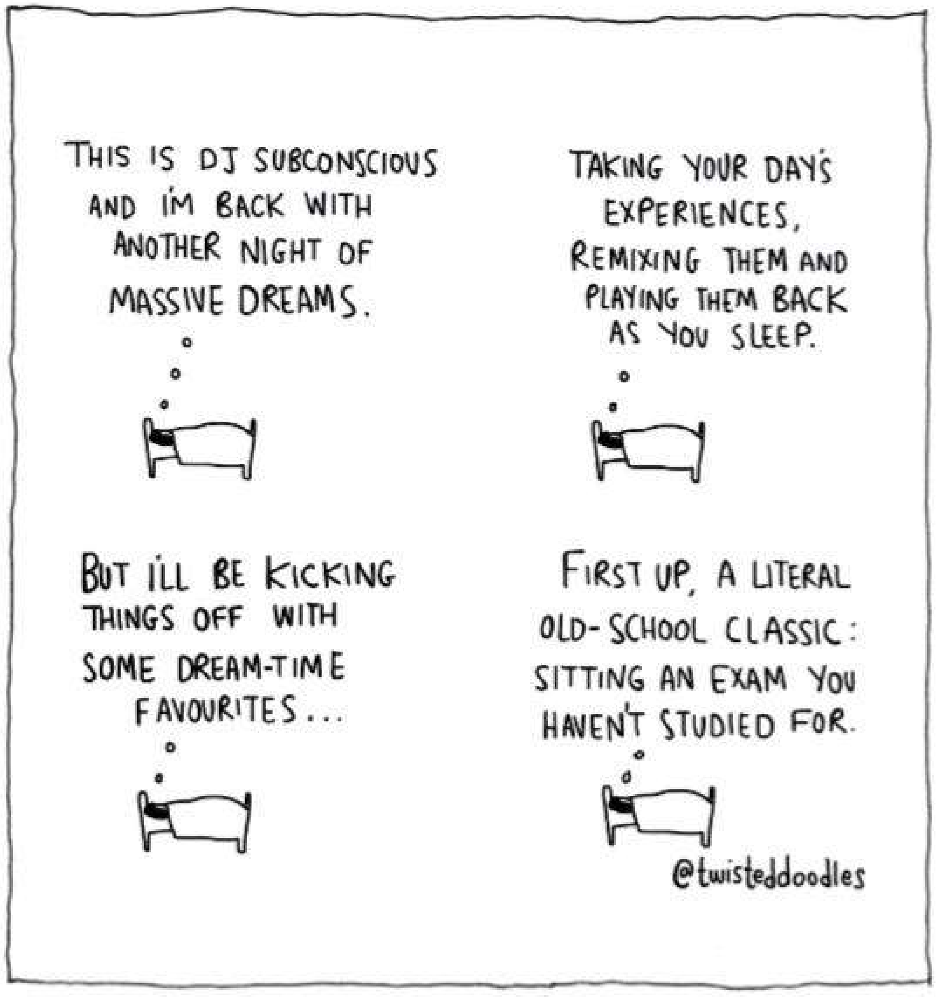
"What makes a great bird photo?", ask Katja Thömmes at the University of Konstanz, Germany, and her colleague Gregor Hayn-Leichsenring in a new paper, "What Instagram Can Teach Us About Bird Photography: The most photogenic bird and color preferences", answering their question almost immediately by collecting 23,818 photos from the social media platform, sorting them into 116 bird families and analysing their "likes".

It turns out that conventional ideas of beauty aren't all they are cracked up to be. There is a distinct inclination for blue birds – mirroring a general human colour preference – but, on the whole, "interestingness, idiosyncrasy, and the situational context all play their part in the aesthetic appeal of bird photos to the human observer".

Toucans, cuckoos and flamingos arouse general indifference, while penguins seem positively scorned, although not so much as waders such as sandpipers and oystercatchers – perhaps, the researchers speculate, because they tend to get snapped in the act of guzzling lugworms.

Top, errrm, billed are in fact birds in the frogmouth group, so named because... well, we'll let you work that one out. With the tawny frogmouth once scorned as "the world's most unfortunate-looking bird", there's hope for all of us yet.

Twisteddoodles *for New Scientist*


THIS IS DJ SUBCONSCIOUS AND I'M BACK WITH ANOTHER NIGHT OF MASSIVE DREAMS.
TAKING YOUR DAY'S EXPERIENCES, REMIXING THEM AND PLAYING THEM BACK AS YOU SLEEP.
BUT I'LL BE KICKING THINGS OFF WITH SOME DREAM-TIME FAVOURITES...
FIRST UP, A LITERAL OLD-SCHOOL CLASSIC: SITTING AN EXAM YOU HAVEN'T STUDIED FOR.
@twisteddoodles

Got a story for Feedback?

Send it to feedback@newscientist.com or New Scientist, 25 Bedford Street, London WC2E 9ES

Consideration of items sent in the post will be delayed

Good hydrations

One colour humans really don't like, we learn from psychometric insights in the above research, is dark yellow. While blue is linked to good things like a clear sky and clean water, yellow is associated with...

An email plops into our inbox. "For the first time, internationally renowned colour experts Pantone has joined forces with nutritionist Lily Soutter and water producer Highland Spring to reveal a new 'Pee Healthy' guide – matching urine colours with Pantone colours – to kickstart a UK-wide conversation amongst Brits to embrace our bodies' natural health indicators on hydration, by checking the colour of our pee!" it froths.

Feedback isn't sure this is a conversation we need to start right now. Not least because we first need to work out where to hold the colour chart while in the act. But we don't disagree with the basic message: drink water, not too little, not too much. Also available from a tap near you.

Dysfunctional shrooms

"Can magic mushrooms really help you understand bitcoin?", *The Guardian* asks, reporting that billionaire German investor Christian Angermayer had first been persuaded to invest in cryptocurrency, and then the active ingredient in magic mushrooms, while on a trip to, and subsequently trip in, the Caribbean.

Whether it is the same functionality that reader Ros Hancock discovered in her Facebook feed with an ad for a mushroom coffee that "provides just half the caffeine you'd find in a regular cup of coffee, along with powerful functional mushrooms to help prolong energy levels, improve alertness and concentration" we couldn't say without self-experimentation. If this column doesn't appear next week, you will know we have woken up a bitcoin billionaire.

Jam today

"Grieved though I always am to see human ingenuity wasted on the development of weapons," writes Rachel Cave from glorious County Donegal in Ireland, "I was intrigued by the prospect of a jam-resistant radio" (24 April, p16). "Any household with a toddler in it would consider that a major breakthrough."

Mayday again

Of which, following our humble contrition (24 April) as we were corrected in our abominable use of "over and out" to end a communication (3 April), John Woodgate writes to say that it was in fact standard procedure in the second world war and later when, in "simplex communication", you had to switch manually between "transmit" and "receive" modes. "I suppose the 'Over' was to remind the operator to switch to receive after out-ing. Or it might have been short for 'communication over'," he writes. "Probably someone else knows for sure (for a given value of 'sure')".

Thank you, John: we too are sure, for a possibly differing value. Humming *The Dam Busters March* while searching for our pot of radio jam, it's out, over and, just in case, out again. ▮

New Scientist
Newsletter

Parental guidance

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